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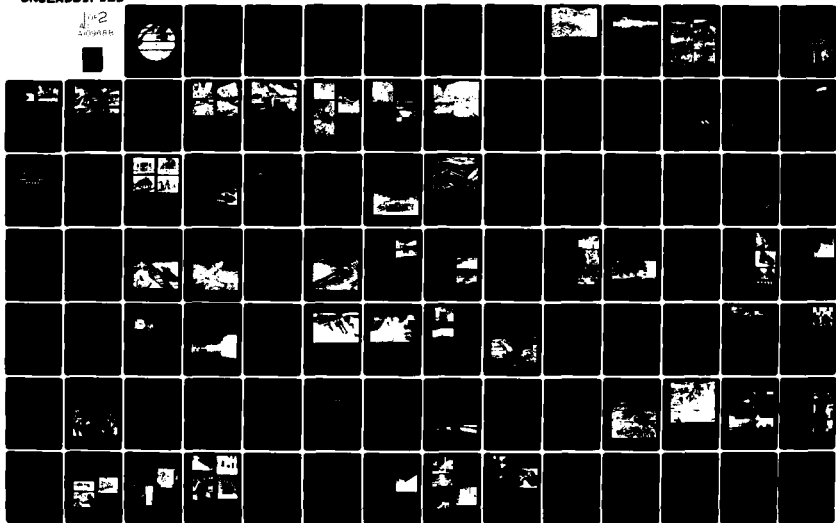
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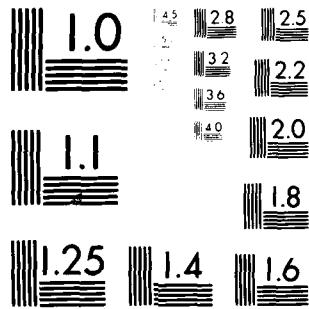
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# COOPERATIVE FLOOD LOSS REDUCTION A TECHNICAL MANUAL FOR **LEVEL II** 4 COMMUNITIES AND INDUSTRY



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COOPERATIVE FLOOD LOSS REDUCTION  
A TECHNICAL MANUAL FOR COMMUNITIES AND INDUSTRY

4

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## ABSTRACT

Flood losses in the United States presently average \$2.2 billion annually and are projected to increase to \$4.3 billion annually in the next two decades. In addition, an average of 200 flood related deaths occur each year and another 80,000 people are driven from their homes. Losses continue to rise in spite of a \$13 billion investment in flood control devices by the federal government.

Losses are high because the Nation's communities and industries are concentrated in the areas first settled along rivers and coasts. The huge investment in buildings and facilities makes it impractical to consider wholesale relocation to flood free sites. Since floods are a natural event that can seldom be prevented, the answer lies in reducing the losses which they cause.

Many means of reducing flood losses are available. Some of them can only be used by local governments while others can be carried out by private property owners. Almost all of the ways to reduce flood losses are more effective when applied as part of a comprehensive program undertaken

cooperatively by local government, industry and other segments of the community.

This manual is a guide for developing a cooperative community program for flood loss reduction. The techniques which may be used and the major considerations in selecting those appropriate to a particular situation are listed. These techniques may be applied on a community-wide or a site-specific basis.

The manual includes a case study of a cooperative program between local government and industry which has produced multi-million dollar savings. The industry described has made numerous adjustments to their physical plant and operating procedures in order to reduce flood losses. Among others, these include relocation of some operations to safe sites, modification of electrical systems, and development of an emergency plan for evacuating materials and equipment during a flood.

Sources of assistance in planning and carrying out various loss reduction measures are identified and selected references are listed.

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# Chapter 1

## INTRODUCTION

This manual is directed to local officials and industrial managers of property subject to flooding. It describes how communities and industries can act cooperatively to reduce flood losses.

Cooperation is critical. Local governments and the private sector both have substantial investments to protect from flooding. Both also have unique capabilities to carry out various actions to reduce flood losses. Cooperative action enables a more comprehensive attack on flood problems than either could mount individually.

### Background

Rivers have played a vital role in the growth of the United States by serving as explorer's routes to inland areas and the paths for western expansion. The rich flat bottomlands of the valleys attracted the first settlers and water wheels powered the industrial revolution. Canals, railroads and highways when built, often followed the early trails along the rivers. Settlements grew beside the rivers and at their confluences with other bodies of water.

Rivers are still important in modern America for water supply, transportation, food production, hydroelectric power, recreation, aquatic habitat and waste assimilation. In many areas, rivers also serve as political boundaries between cities, counties and states.

The early pattern of development, coupled with the continuing importance of rivers, is obvious on today's maps. Almost all of the Nation's large cities and most of the smaller ones are located either along an ocean, lake or beside a river. Unfortunately, many of these developed areas are floodplains--lands subject to flooding.

The concentration of people and wealth on floodplains is out of proportion to their size. While all of the floodplains together amount to only about 7 percent of the country's total land area, they contain over 7 million structures and billions of dollars worth of community facilities and private property.

These structures and the people who work and live in them are subject to flooding. The river valleys and flat bottom lands which first attracted settlement were formed and are continually shaped by frequent small floods and less frequent large ones. Flooding is a natural event, yet people and property are put in jeopardy hundreds of times each year as one body of water or another asserts its natural right to its floodplain.

Industrial buildings and their contents are especially vulnerable to flooding. The industrial areas in many communities occupy the lowest lands

<sup>1</sup>Goddard, James E. An Evaluation of Urban Flood Plains. Technical Memorandum No. 19. American Society of Civil Engineers. New York, NY. December 1973.



*Early settlements were often near a river or on the shore of a lake or ocean. As a result, many cities are subject to flooding.*

closest to the river, making them the first flooded and the last to be free of flooding. In addition to large buildings, industrial facilities frequently contain expensive machinery and valuable stockpiles of raw materials and finished products, all contributing to the risk of extraordinarily high losses.

Communities have a special interest in the health and well being of local industries. Aside from industry's importance as a main source of revenue and economic growth, an industry closed by floods often means workers out of a job. For one-industry towns, the results can be disastrous.

The important tie between community and industry was made painfully clear throughout much of the northeastern United States in 1972 by the severe flooding accompanying Tropical Storm Agnes. In Pennsylvania, all 67

counties were declared disaster areas and more than 50,000 people were reported to be out of work due to the storm.

In the hard hit Susquehanna River Basin, people began searching for a wider range of ways to reduce flood losses. In Lycoming County, Pennsylvania, one industry developed and implemented a comprehensive flood preparedness plan that included a flood warning system to predict flooding of a nearby stream and the West Branch Susquehanna River. The preparedness plan proved so successful that damages were reduced 93.2 percent when a somewhat smaller but still serious

<sup>2</sup>U.S. Army Corps of Engineers, Baltimore District. The Corps Responds: A History of the Susquehanna Engineer District and Tropical Storm Agnes. Baltimore, MO. (undated).



*Industrial areas in many communities, such as this one in Pittsburgh, Pennsylvania, occupy the lowest lands closest to the river and are especially vulnerable to flooding.*

flood occurred in 1975. The warning system was eventually expanded to cover all the major streams in the County through the cooperative efforts of industry, the County and the National Weather Service.

The success of the cooperative program in Lycoming County made two things clear. First, other industries in the County could benefit by being prepared to take advantage of the system's early warnings; and second, the program was a good example of what could be done in other areas to reduce flood losses.

A seminar focussing on flood warning and industrial floodproofing was held in Williamsport, Pennsylvania, in April of 1979. The seminar was sponsored by Lycoming County and the SEDA-Council of Governments, a 10-county regional planning and development agency. Speakers at the seminar

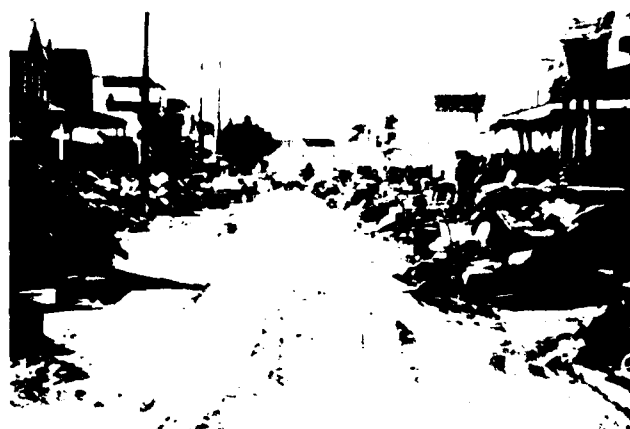
included local officials and industry managers involved in operating the cooperative warning program as well as consulting engineers and representatives of state and federal agencies. The audience included engineers and managers of industrial plants, bankers, and representatives of local governments.

The seminar's success showed the value of telling what had been accomplished in Lycoming County to an even wider audience. Over the course of the next year, the U.S. Water Resources Council made arrangements for three federal agencies to jointly support a grant to the SEDA-Council of Governments for that purpose. A steering committee, composed of federal, state and local government representatives was organized to oversee preparation of this technical manual, a slide show and a movie. Each of the products was to focus on a different aspect of the cooperative program.

The slide show, "Early Flood warning", explains the principles of self-help, and cooperative effort in establishing and operating a flood warning system using volunteer observers for the collection of rainfall and streamflow data. It also describes the use of warnings as a basis for protective action and the type of steps which

can be taken to save lives and reduce both community and industrial damages.

The movie, "Watch Along the Watershed", describes the development of the industrial flood preparedness plans, plant adjustments, and the cooperative flood warning effort between local government and industry.



*Tropical Storm Agnes caused disastrous losses throughout the Susquehanna River Basin.*

This publication--the technical manual--provides local officials and industrial plant managers with more detailed information needed to begin development of a flood loss reduction program. It describes the available tools, procedures that can be used, and sources of assistance. The manual also includes a description of the cooperative program between local government and industry in Lycoming County, Pennsylvania.

## **Purpose**

The purposes of this technical manual are to:

- Emphasize the need for flood loss reduction.
- Provide information on the basic concepts and tools for flood loss reduction.
- Describe procedures for selecting appropriate flood loss reduction measures.
- Identify sources of technical information and assistance.
- Describe procedures for developing a flood loss reduction plan.
- Provide an example of cooperative community and industry action to reduce flood losses.

## **Scope**

The manual presents material in a step-by-step fashion. Chapter 2 provides a brief description of

national flood losses and some specifics about community and industrial flood problems.

Chapter 3 describes a variety of flood loss reduction measures which can be undertaken independently by owners and operators of public and private property. Some of the measures can also be carried out as cooperative programs between government and the private sector. Chapter 4 describes additional flood loss reduction measures which usually require governmental participation. Some of those measures are prime candidates for cooperative action between government and industry.

Chapter 5 deals with developing a cooperative program. It describes how to analyze the severity of the flood problem, the information needed to plan a flood loss reduction program, and the important factors to consider when selecting particular measures for use.

Chapter 6 describes the development and operation of the cooperative flood warning program in Lycoming County and one firm's preparedness plan. It demonstrates the relative ease of establishing and operating one kind of flood loss reduction program and the significant benefits which can result.

The manual has two appendices. Appendix A lists references providing more detailed information on reducing flood losses and information on obtaining each referenced item. Appendix B lists federal, regional and state agencies which have responsibility for some aspect of flood loss reduction and which can often provide assistance of various types.

## Chapter 2

### THE FLOOD PROBLEM

Economic and social flood losses in the United States are increasing rapidly. All parts of the Nation are affected.

Chapter 1 noted that flood losses were a serious problem. This chapter describes the major types of floods which occur, size of national flood losses and the prevalent types of losses.

#### Types of Floods

Several types of flooding affect the United States. The most common are:

- Coastal flooding along oceans and lakes.



#### *Coastal Flooding*

*There are many types of flooding, some areas are subject to more than one type. Solving flood problems requires a good understanding of the nature of flooding which might occur and the needs of the affected area.*



*Sheet Flooding*



*Riverine Flooding*

- Flash flooding.
- River flooding.
- Sheet flooding.

Flooding of barrier islands and coastal areas along oceans and large lakes is usually associated with high waves caused by severe storms. Along the southeast Atlantic and Gulf Coasts, hurricanes can cause "surges" of water tens of feet high which travel inland with devastating force. A hurricane surge which struck Galveston, Texas, in 1900 killed 6,000 people. The West Coast and Hawaii are subject to flooding by "tsunami", another type of ocean wave caused by undersea earthquakes or volcanic activity. Some lands along lakeshores and seacoasts are also flooded because the land subsides or sinks, usually due to heavy withdrawals of water or oil. Lakeshores may also be flooded by a "seiche" in which a combination of wind and changes in atmospheric pressure or an earthquake causes the surface of the lake to oscillate over a period of minutes or hours.

Flooding which occurs within a few hours after a storm or other causal event is termed a "flash flood". This type of flood occurs most commonly along small streams in mountainous areas. Flash floods typically rise

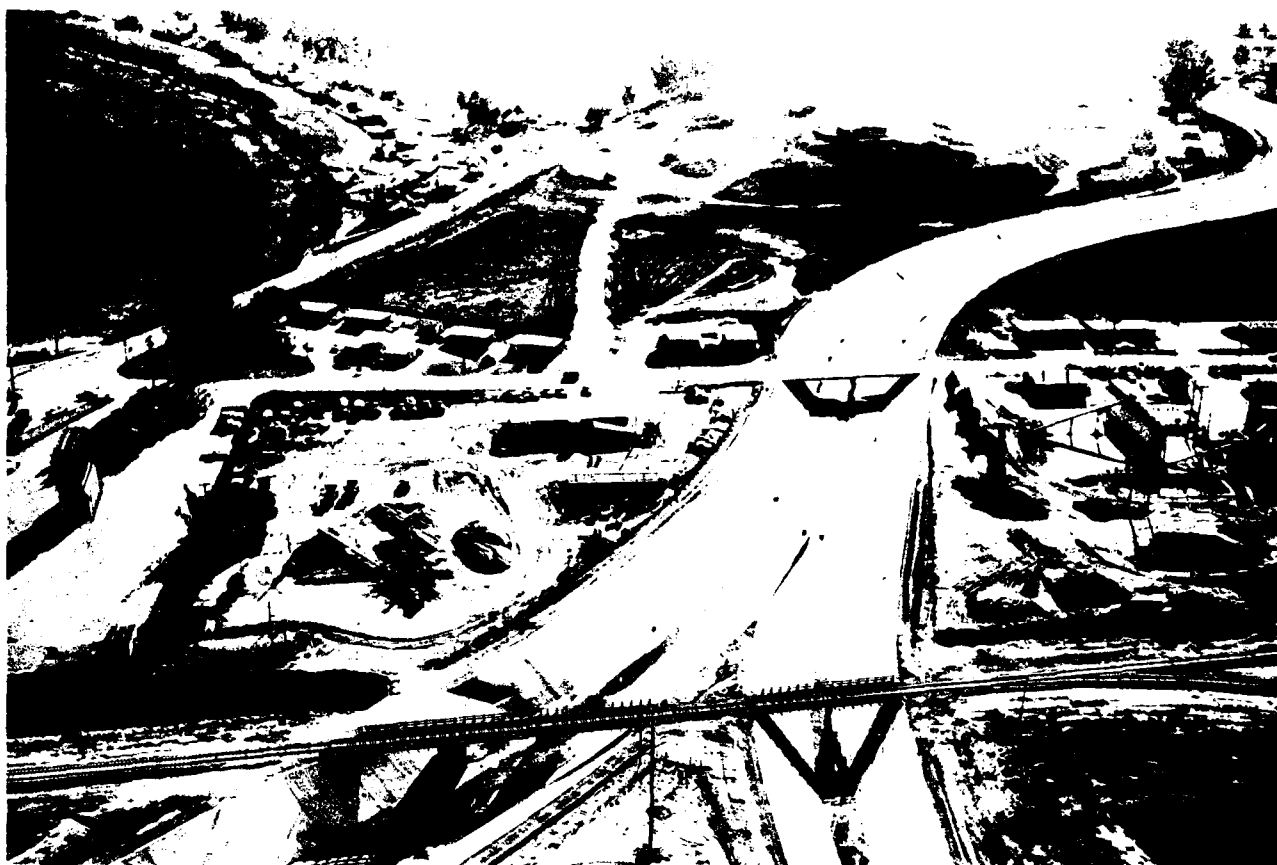
quickly to a peak and move downstream rapidly, carrying large amounts of debris. The high velocity of the water and the quickness with which flash floods occur make them exceedingly dangerous. The 1972 flash flood in Big Thompson Canyon in Colorado, for instance, killed 15 people.

Cases in which waters rise more slowly are referred to as "river or fluvial floods" or simply floods. This type of flood predominates on larger streams and primarily affects property. Ample time and warning are usually available for people to retreat as the flood waters advance.

Sheet flooding results from rainfall or snowmelt on its way to the stream. It consists of a thin sheet of flood waters, several inches to a couple of feet deep, which flows unconfined over the land. It occurs mostly in areas which are relatively flat and poorly drained. While sheet flooding can sometimes be deep enough to cause significant damage, it is not usually as dangerous as other types of flooding.

## **National Flood Losses**

The federal government has invested some \$13 billion in flood control works over the past several



*Many flood problems can be relieved by dams, channels such as this one in Escondido, California, and other public works. However, these measures are generally expensive.*

decades.<sup>3</sup> Despite this investment and the significant savings achieved each year, flood losses have continued to grow as more people, structures and facilities have crowded onto the floodplain.

Floods accounted for about 75 percent of all presidential disaster declarations during the 70's.<sup>4</sup> Average annual flood losses to the Nation were

<sup>3</sup>U.S. Water Resources Council. The Nation's Water Resources, The Second National Water Assessment; Part I, Water Management Problem Profiles. Washington, DC, April 1978.

<sup>4</sup>U.S. Water Resources Council. Floodplain Management Handbook. Washington, D.C. 1981.

estimated in 1975 to be about \$2.2 billion and are expected to climb to over \$3.6 billion in 1985 and to about \$4.3 billion by the year 2000.<sup>5</sup> Additional billions are spent each year on disaster assistance for communities, businesses and individuals in flooded areas. Flood insurance<sup>6</sup> claims paid in 1979 were \$482,375,053.

<sup>5</sup>U.S. Water Resources Council. The Nation's Water Resources, The Second National Water Assessment; Part I, Water Management Problem Profiles. Washington, D.C. April 1978.

<sup>6</sup>Federal Insurance Administration, Federal Emergency Management Agency. Exhibit 1, Flood Insurance Manual Revision. Washington, D.C. October 10, 1980.



Flood losses are not distributed uniformly across the Nation. Some areas have flood problems significantly greater than others. But no region or state is totally immune to flooding, including the normally dry deserts of the Southwest. Figure 1 shows the distribution by region of flood losses for 1975.

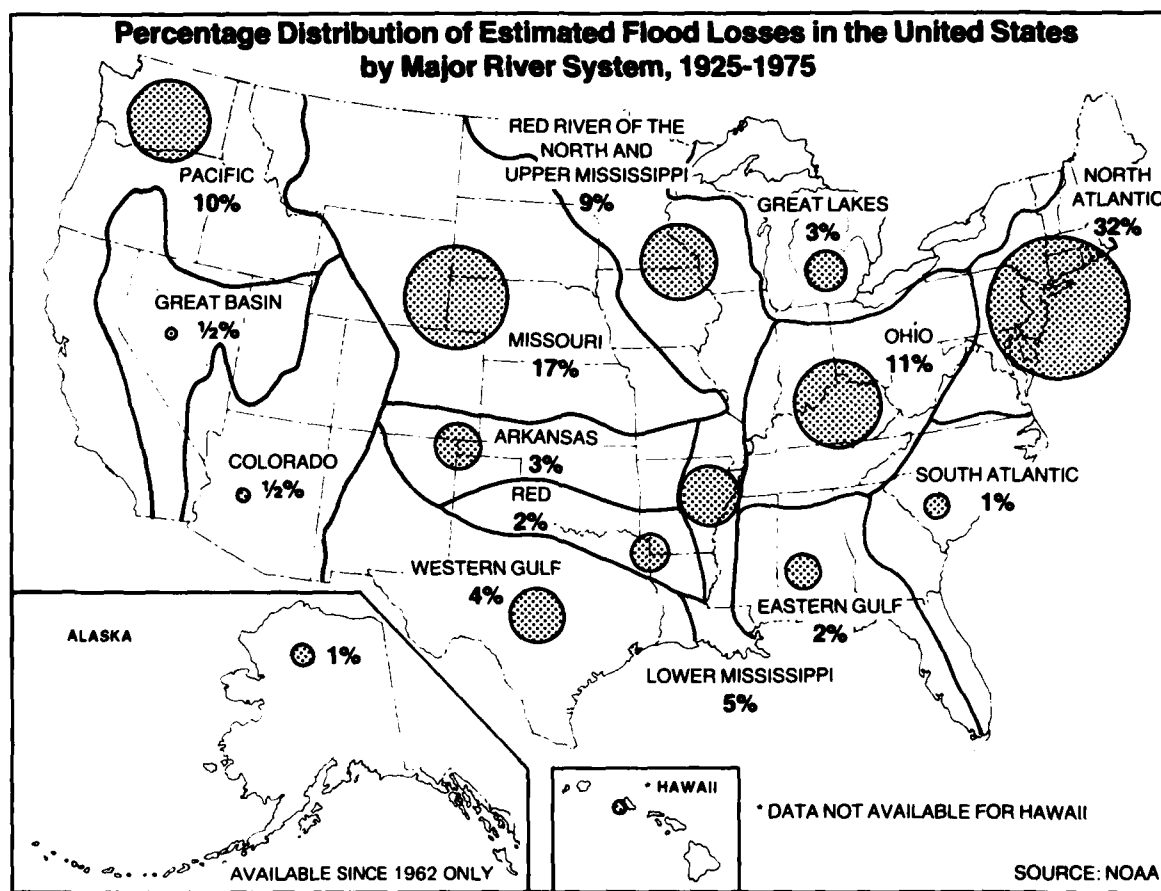
Economic losses due to floods include direct damages, indirect damages and other costs. Direct damages are those caused by the force of the flood waters or the effect of inundation. They include such things as:

- Destruction of roads, bridges and utility systems.
- Collapse or flotation of structures.

- Loss of legal, financial and other documents and records.
- Damage to or destruction of furniture, fixtures, appliances, machinery and other building contents.
- Siltation and erosion of cropland.

Indirect damages are those that occur as a secondary effect of direct damages. Examples of indirect damages are:

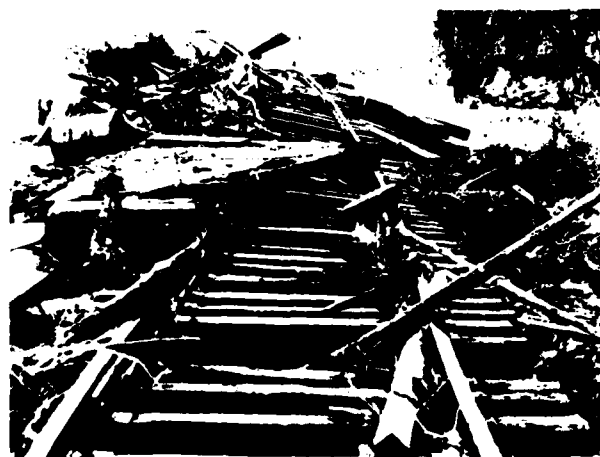
- Losses or damage due to disruption of services (e.g., electric, water, gas, highway, bridges).
- Fire and explosion due to inundation of electrical and gas systems.



Totals may not add to 100% due to rounding

FIGURE 1. NATIONAL FLOOD LOSSES

*Flood losses vary from region to region and from year to year. However, flood problems exist in every state.*



*Direct damages are those caused by the force of flood waters or the effect of inundation.*

- Loss of local, state and federal tax revenues.

Costs other than damages include all of the identifiable expenses associated with flooding other than damages to property. Examples of such costs are those for:

- Evacuation and reoccupation.
- Care of evacuees.
- Debris removal and cleanup.
- Business interruptions.
- Interest free or low interest rehabilitation loans.

There are also unmeasurable economic costs due to flooding. These intangible costs include such things as reductions in property value and the diversion of effort from regular activities.

Floods also cause death and suffering. An average of about 200<sup>7</sup> deaths related to flooding are reported each year although some floods, like the cited examples of Big Thompson Canyon and Galveston, Texas, may kill hundreds or even thousands of people in

<sup>7</sup>U.S. Water Resources Council. Floodplain Management Handbook. Washington, D.C. 1981.



*Flood damage to roads and railroads involves many secondary costs. Disruption of transportation may cause losses to industries and others not affected directly by flooding.*

a matter of minutes. Aside from deaths and the even larger number of injuries, about 80,000<sup>8</sup> Americans are forced from their homes each year by floods. And each year thousands of families and businesses face financial hardship as a result of flood losses.

There are also intangible social effects of floods. These include such things as:

- Public health problems.
- Creation of slum areas due to repeated flooding.
- Anxiety over future floods.
- Loss of valuable housing stock.

<sup>8</sup>Ibid.

## **Types of Flood Losses to Communities and Industry**

Communities and industries share a concern for the lives of their residents and workers, but safety is largely a matter of the response which each individual and family makes to a flood threat. Excepting those unusual floods which kill large numbers of people, the major effect of floods on communities and industries is the economic loss which occurs.

The major direct economic losses to public property usually stem from damage to support facilities such as roads and bridges, water systems, sewage collection systems and waste treatment plants. Damage to office buildings, libraries, and other structures and their contents is usually



less severe but occasionally can be very large. Damage to utility and other community systems may sometimes cause services to be curtailed for months until rebuilding or replacement is completed. In addition to the cost, this causes serious inconveniences and secondary problems for the public such as disruption of traffic, unsanitary conditions and lack of communications.

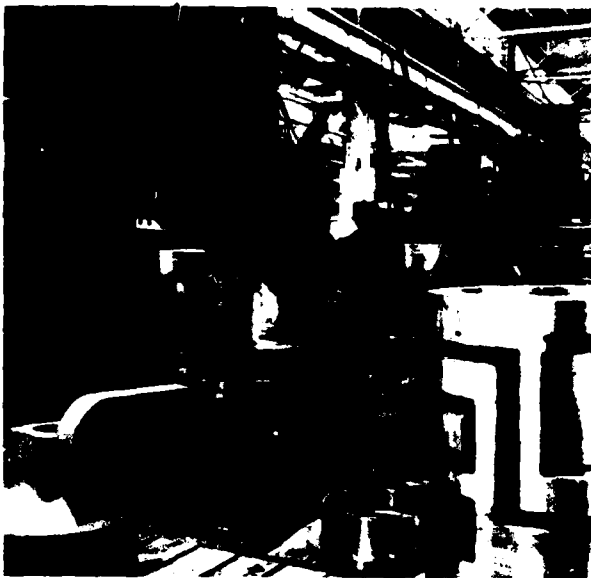


*Flash floods have tremendous destructive force. This area was devastated by the 1977 flash flood and dam failure at Toccoa, Ga. At least 38 lives were lost.*



*The cost of floods is more than just the damage to property. It also includes loss of life and other social impacts as well as the costs for rescue, care of evacuees, business interruptions and cleanup of debris.*

Industries differ from one another and from communities with respect to the types of damage which are most important. Unlike communities, only a small part of most industries' investment is in utilities, roads, bridges and other supporting facilities. Their major investments and most serious damages are more likely to be linked to buildings, specialized mechanical and electrical equipment, and products. The type of damage most important in a particular case depends on the physical plan involved and the sort of operations carried out. If floods force curtailment of production for any reason, business interruption losses are likely to be one of the greater, and sometimes the greatest, loss.



*Industrial plants often contain specialized machinery which is expensive and difficult to replace. Electrical motors and precision equipment are easily damaged.*

Floods have short-and long-term fiscal impacts on industries and their host community. Although the short-term impact is important, the long-term impact on the community's economic structure may be more serious.

In the short-term, interruption of production often means an immediate loss in sales. Inability to fulfill orders on a timely basis may even lead to a permanent decrease in a firm's market share. Both of these impacts may result in increased unemployment until pre-flood production levels are resumed. Industrial firms may also suffer economic losses from a flood even though their facilities are not actually damaged. For example, suppliers of flood-damaged manufacturers face reduced sales until customers have resumed operation and may also be forced to shut down or lay off employees. Conversely, damage to a supplier may force another industry to suspend production. This "ripple" effect increases unemployment in the community.

Unemployment from reduced or stopped manufacturing activities in turn affects the services and retail trade sectors. They suffer as a result of the smaller amount of money circulating in the local economy. The end result for the community is a widespread decrease in personal income and reduction in tax revenues. The reduction in tax revenue comes at a particularly inopportune time since the cost of public service and maintenance usually increases significantly in the aftermath of a flood.



*Flooded industrial plants may be out of production for months, causing losses to employees and suppliers as well as to owners and stockholders.*

From a longer-term perspective, firms which suffer direct or indirect losses from floods are not likely to expand or locate in the area if a suitable alternative location is available. While the movement of physical capital is relatively slow, the relocation of manufacturers and their suppliers can have a domino effect, eventually affecting the location of housing and retail sales establishments.



*This industrial plant in Papillion, Nebraska, sustained severe flood damage. Such extensive damages can sometimes cause an industry to close down permanently.*

Transformation of a community's economic base from manufacturing to a service and retail trade base may occur without serious flooding, given the decreasing national role of the manufacturing sector. However, a flood

may accelerate the process and, instead of an orderly and gradual economic change, face the community with steeply declining tax revenues due to lower personal incomes, a lower tax base, and loss of population.

# Chapter 3

## SITE-SPECIFIC ADJUSTMENTS

Owners and operators of property subject to flooding need not be dependent on others for its protection. There are numerous means of protecting property which can be carried out on an individual basis.

Persistent and serious flood problems in the United States have resulted in development and use of a wide variety of loss reduction measures. Two distinctive types of measures have emerged: site-specific measures which may be used to reduce losses to individual properties; and community adjustments which provide more widespread protection. This chapter describes the site-specific category of measures including:

- Closure of openings.
- Raising existing buildings.
- Elevating new structures.
- Small walls and levees.
- Permanent relocation.
- Rearrangement and modification of contents and facilities.
- Temporary relocation of building contents.
- Recovery arrangements.

All of the above measures can be implemented on a unilateral basis by property owners. Many can also be undertaken as public programs or as cooperative programs between government and private property owners. Table 1 summarizes the various measures with respect to purpose, applicability and

economic considerations. These measures are effective for use on isolated structures and in areas where major public works for flood control are not feasible.

### Caution

Selection of the most appropriate and cost-effective means of protection for a particular property and flood hazard can be complex. Inappropriate or improper use of a protective measure may result in unnecessary cost, increased flood damages, or both. The assistance of experienced professionals should be obtained in selection of the measures, their design, and supervision of their implementation.

Assistance in planning and carrying out the types of flood loss reduction activities in this chapter is available to state and local governments through the Corps of Engineers Flood Plain Management Services Program, the Regional Insurance and Mitigation Offices of the Federal Emergency Management Agency and state offices of the U.S. Soil Conservation Service. Assistance is also available to both local governments and private parties from consultants and engineering firms. Some state agencies also provide such technical assistance.

TABLE 1  
SUMMARY OF SITE-SPECIFIC FLOOD LOSS REDUCTION MEASURES

Measure	Purpose	Structure Type <sup>a</sup>	Applicability Flood Depth <sup>b</sup>	Economic Considerations
Closure of Openings	Prevent water from entering structure through doors, windows and other openings.	All size structures of brick, brick veneer stone or other impervious materials. Best for structures without basements.	0-3 ft. for residences Up to 6 ft. for commercial and industrial structures.	Tends to be expensive for all but the most well suited structures. Most feasible when incorporated in original building design.
Elevating Existing Structures	Raise structure above flood level on walls or posts.	Structures of wood or brick veneer small enough to lift with house moving equipment.	0-6 ft.	Often feasible for small structures, especially where site has special advantages for occupant. Does not reduce basement losses.
Elevating New Structures	Elevate structure above flood level on earth fill or supporting members.	All types and sizes of structures.	Unlimited	Generally involves only a small additional cost.
Small Walls & Levees	Keep water away from damageable property by building a barrier.	All structures. Least applicable for commercial buildings with show windows.	0-6 ft.	Feasible for many structures. Enables protecting landscaping, equipment, and other property in addition to structure.
Reorganization of Space	Move contents to upper story, modify electrical system and other building components to withstand flooding.	Most industrial and commercial structures and multi-story residences.	Unlimited except by structure characteristics.	Variable. Some reorganization is of nominal cost and likely to be feasible in all cases.
Temporary Relocation	Remove contents from structure for duration of flooding.	All structures.	Unlimited	Feasible in all cases where contents are of more than minimal value.
Recovery Arrangements	Expedite return to normalcy to minimize business losses and secondary problems.	All structures to some extent but primarily commercial and industrial structures.	Unlimited	Feasible in almost all cases.

<sup>a</sup>Comments on applicability and economic considerations are generalizations only. Many variations exist for particular situations.

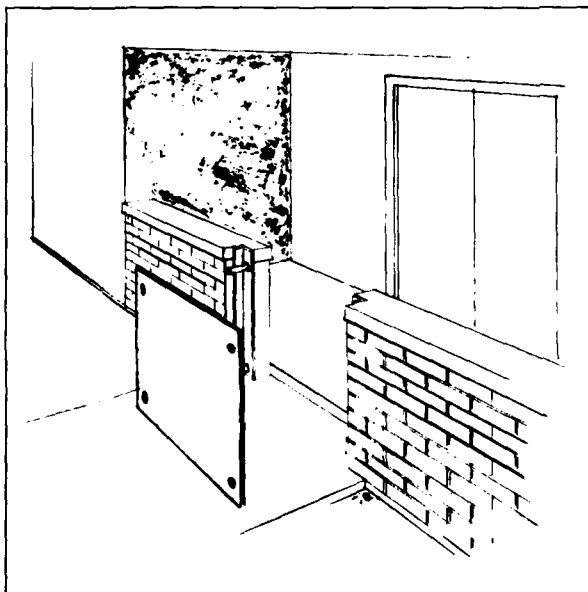
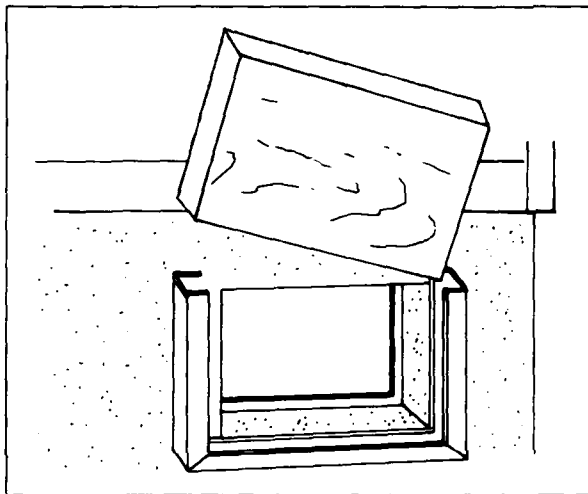


## Closure of Openings

The objective of this measure is to make a structure more resistant to the entrance of water.

### Description

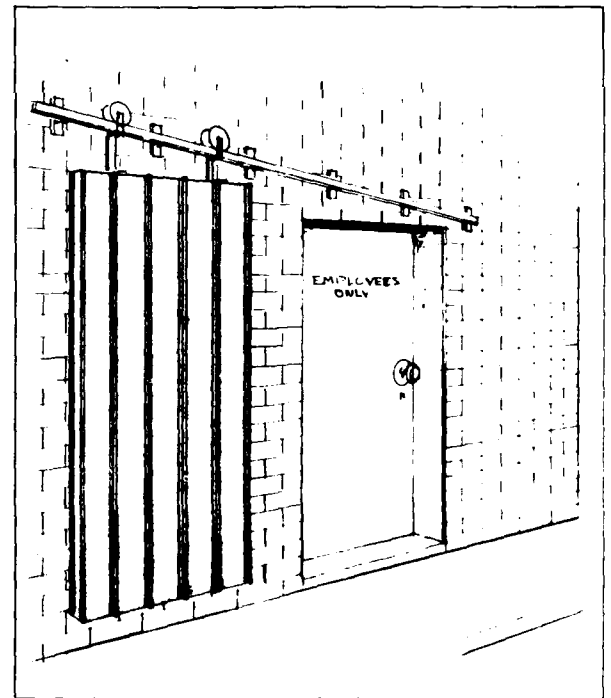
Structures with relatively impermeable exteriors can be made more flood resistant by waterproofing walls and floors and either temporarily or permanently sealing doors, windows and other openings.



*Temporary flood shields can be put in place to help prevent flooding of structures.*

Usually doors do not seal tight enough to prevent seepage. Installation of a rubber gasket and a means for pressing the door against the gasket is adequate for flooding up to about one foot in depth. A more certain means is the use of aluminum, steel or wood flood shields made to the height and width desired. Shields may be permanently installed at the doorway on hinges or rollers or stored nearby for installation on brackets or anchor bolts at the time of a flood. Unused doorways can also be permanently closed with concrete blocks or bricks.

Normal window glass will not withstand flood forces and is especially vulnerable to breakage by floating debris. Shields are commonly used to protect windows from breakage and prevent water from entering. As with doorways, shields may be permanently installed on hinges or rollers beside or above the opening or stored elsewhere and installed temporarily during floods. Another alternative is to



*Flood shields for doors and other openings can be stored near the place of use on rollers or hinges to avoid being misplaced and to enable immediate use when needed.*

install heavy duty plexiglass or, for basement windows, glass block. Large display windows in commercial structures are sometimes protected by installing weep holes at the base of the window. This allows water to enter to equalize the pressure on both sides of the window. The water is then prevented from entering the remainder of the structure by a parapet wall. Windows not needed can be permanently closed with blocks, brick or other impermeable material.

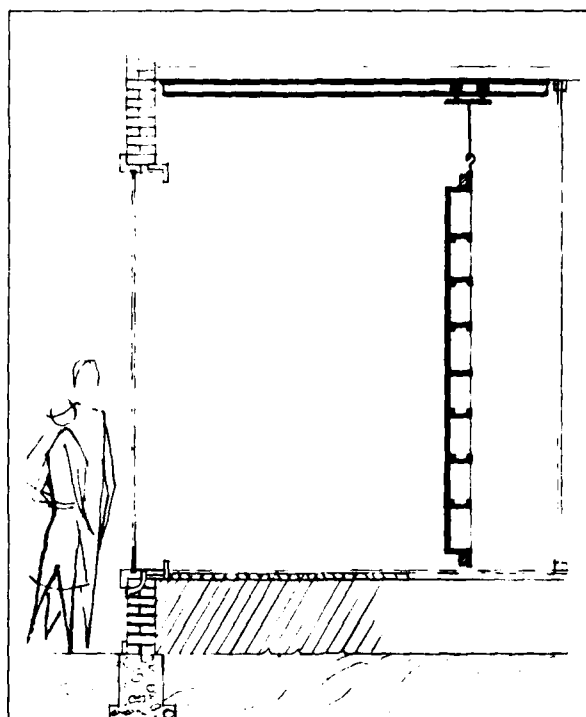
Waterproofing sealants are sometimes applied to generally impermeable walls and floors to further reduce seepage. Sealants are particularly effective on brick veneer, cement block, reinforced concrete and similar masonry type surfaces. Cracks in masonry can be filled by caulking.

Basements are often flooded by water backing up through the sewer line. This problem can be prevented by installation of a gate valve or check valve on the sewer line. Anti-backflow valves should be located outside the structure if there is a possibility that line pressures occurring during a flood might break the line. For very shallow flooding, backflow can be stopped inside the building by valves, plugs or standpipes at the floor drain.

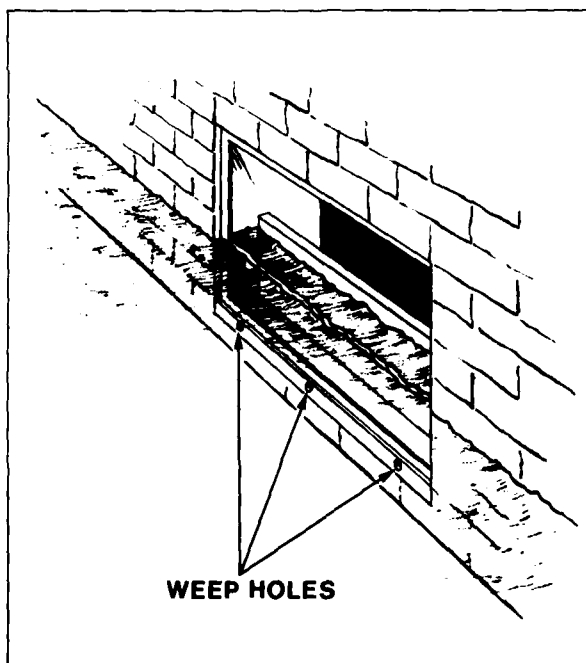
Some seepage is likely to enter a structure despite waterproofing precautions. It is desirable, therefore, to have a sump pump available which discharges above the design flood elevation. A reliable source of power, such as a gasoline operated generator, must be available for pump operation.

#### Caution

Blocking entry of flood waters into a building prevents equalization of inside and outside pressures. Most structures are not designed to withstand lateral loads on basement and above ground walls or uplift on floor slabs. Improper use of this technique can result in serious damage, collapse or flotation of the structure.



**Note: Windows remain vulnerable to breakage by debris**

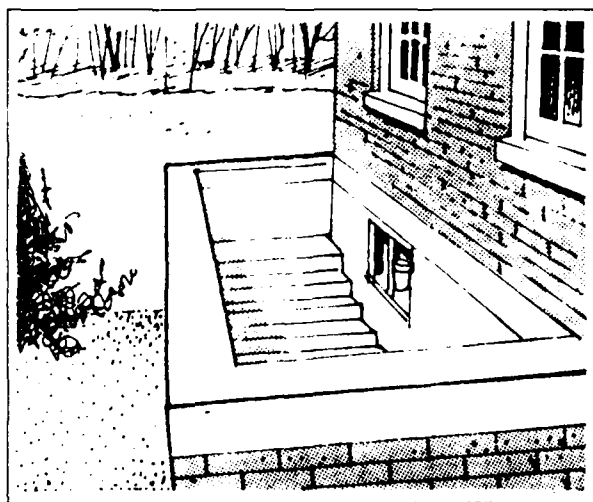


*Show windows and other glassed areas can be sealed off by fixed or movable walls. Water must be allowed to enter between the glass and the wall to equalize pressures and prevent the glass from breaking.*

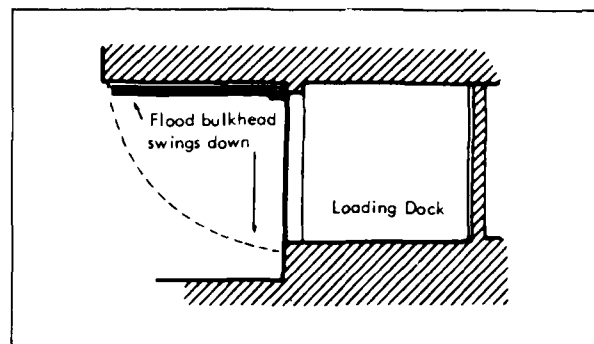
## Applicable Types of Property

Closure of openings is applicable only to walled structures. While many types of walled structures could be made watertight if costs were disregarded, the measure is generally limited to use with structures which:

- Are constructed of brick, brick veneer, concrete, cement block, stone or other relatively impermeable materials.
- Have a limited number of openings which can be permanently or temporarily sealed.
- Have the structural strength to resist hydrostatic and bouyant forces to the water level for which the protection is designed.
- Have or can be provided continuous electrical power during floods for operation of a sump pump to take care of seepage.



Low walls around stairwells help prevent flooding of basements. An access opening fitted with a shield can be provided in the wall or steps can be added to enable climbing over the wall. Entry of water through basement windows can be prevented by replacing them with brick or glass block.



*Loading docks or large entrances to buildings can be sealed off with shields hinged for overhead storage.*

## Limitations

Most structures have at least some openings which cannot be either permanently or automatically closed. Plans for temporarily sealing openings after a flood warning is received require that knowledgeable personnel be available on a 24 hour basis. Sufficient advance notice of an impending flood is also necessary.

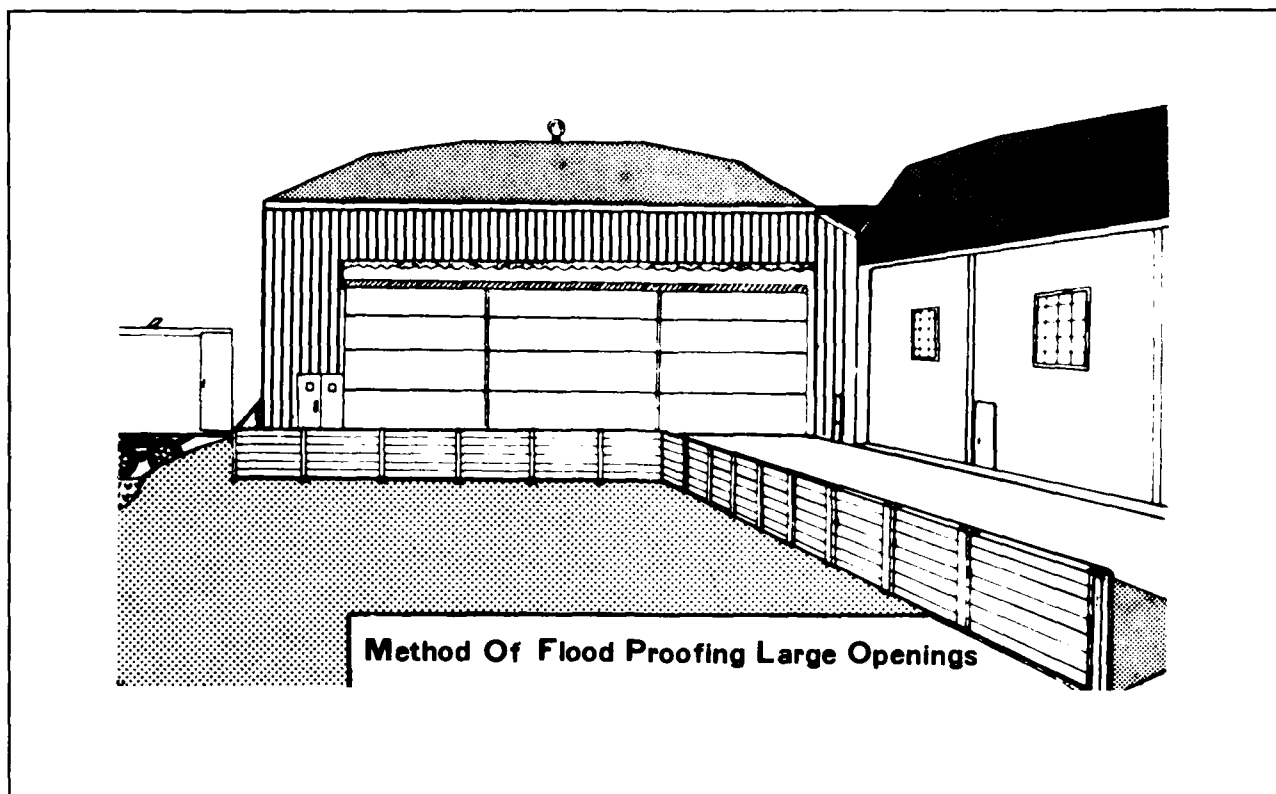
### Caution

Closure of openings is not a substitute for evacuation. Remaining in a structure would be hazardous if the structure or a closure fails or if flood depths exceed the design level of the closures.

Closure of openings may adversely affect the appearance of a structure. Some adjustments, such as bricking up or otherwise permanently closing doors may disrupt normal traffic patterns or cause other inconveniences.

## Economic Considerations

Preventing the entry of water eliminates damage to building interiors and contents. However, it does not reduce damages to building exteriors, landscaping or other property outside the building.



*Buildings with many openings can be protected from flooding by installing a temporary or permanent wall extending around necessary parts of the building.*

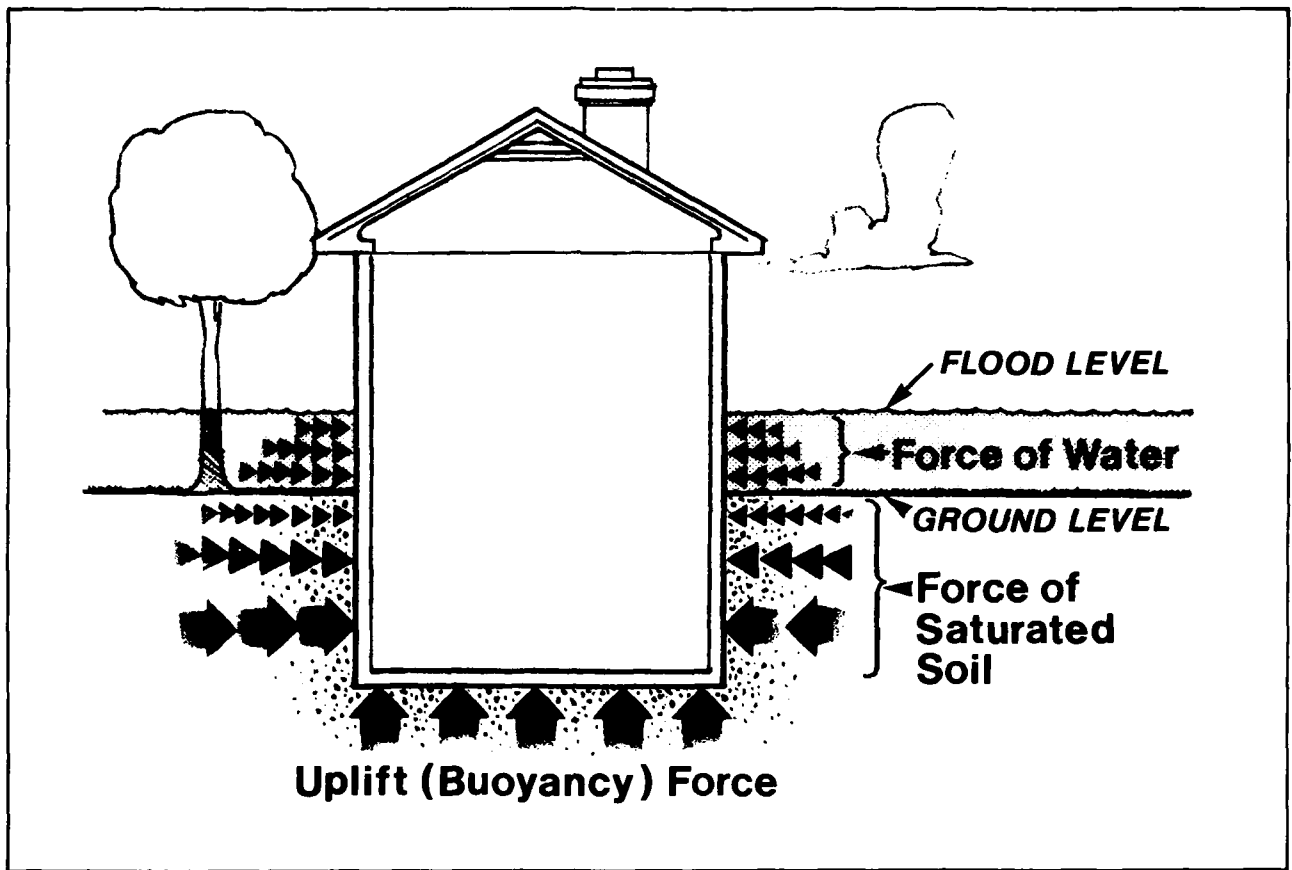
The measures only provide protection up to the design level. Losses due to floods exceeding the design level are not reduced and, in some cases, may be increased.

The cost of making structures water resistant varies greatly depending on building type, size and strength. For small structures without basements, the major costs are those for fabricating and fitting shields to openings, permanently closing unused openings, sealing exterior walls and the floor slab, installing a valve on the sewer line to prevent backflow, and installing a sump pump to drain any seepage. Costs increase rapidly for buildings with basements if structural strengthening of the walls and floor is necessary. If flood depths are expected to be over two to three feet above the lowest level of the protected area,

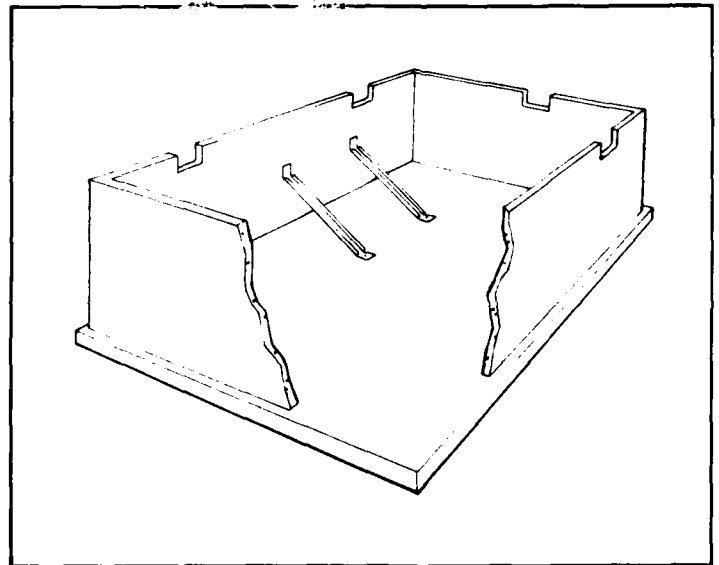
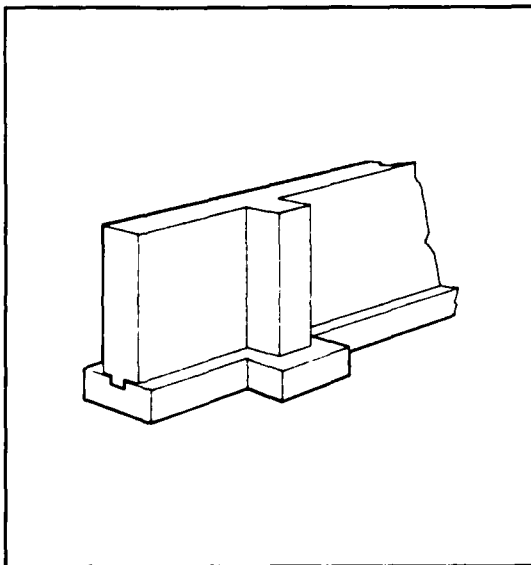
structures should be anchored to prevent flotation.

Commercial structures are generally sturdier than residential structures. Protection up to six feet above ground level may be possible in reinforced concrete structures without basements, provided there are no large openings in the exterior walls.

Without special strengthening, basements may begin to fail when outside water levels reach four to five feet above their floor level. Therefore, residential and commercial structures with basements in pervious soils should not be protected much above the height of basement windows without a comprehensive analysis of potential loads. In most cases, strengthening of basement walls and floors will be sufficiently expensive to make the measure uneconomical.



*Flood waters create lateral and bouyant forces which most structures are not designed to resist. Walls may collapse or basement floors may buckle if forces become too great.*



*Basement walls and floors should be strengthened if significant flooding is anticipated.*

## **Elevating Existing Buildings**

The objective of this measure is to elevate structures and their contents above anticipated flood levels.

### **Description**

Existing structures can often be elevated to reduce flood damages. The principal steps in raising a structure are:

- Preparing the structure for lifting.
- Lifting the structure.
- Constructing an elevated foundation.
- Lowering the structure onto the elevated foundation; and
- Preparing the structure for use.

The preparation of a structure for lifting depends on its characteristics. It usually requires removal and temporary storage of contents, disconnection of plumbing, wiring and other utilities, and separation of the building from its foundation. Appurtenances to buildings such as fireplaces and porches may also require removal. Usually, brick veneers must be removed or braced and vegetation cleared. Structures in poor condition or vulnerable to cracking may require extensive bracing.

Lifting is normally accomplished with house moving equipment. This requires access under the first floor of the structure for placement of beams and jacks. The structure must be lifted high enough to permit construction of the elevated foundation.

Elevated foundations are often prepared by adding courses of concrete block to the original foundation. Alternatively, poles or piers may be used to support the structure. While less common, the site can be raised with earth fill and a new foundation constructed.

Preparing the elevated structure for use requires a number of adjustments including:

- Extension and reconnection of plumbing, wiring and utilities.
- Reconstruction of driveways, walks and steps.
- Replacement or reconstruction of brick veneers and appurtenances removed from the structure.
- Replacement of contents.

Depending upon the nature and age of the structure, modifications may be necessary to update utilities to meet current code requirements. It may also be necessary to add insulation to exposed areas and provide flood protection to the extended utilities. In addition, the furnace, water heater and other vulnerable equipment must be relocated to the raised structure if damages to them are to be avoided in future floods.

### **Applicable Types of Property**

A wide variety of existing structures could be raised. However, considerations of cost restrict the practical applicability of this measure to structures which are:

- Accessible below the first floor for convenient placement of beams and jacks.
- Light enough to be raised with ordinary housemoving equipment.
- Small enough to be lifted without partitioning.
- Capable of being lifted without a high risk of damage.

Small wood frame, commercial and residential structures are particularly well suited for raising if they have basements or are built over crawl spaces. Small brick and concrete structures with access below the first floor can also be raised but with more



*This house was elevated on columns to provide safety from floods.*

difficulty and cost. Structures on concrete slabs are generally not suited for raising because of the difficulty and expense to avoid cracking the slab. Structures involving common walls, such as row houses, are also not suited for raising.

### **Limitations**

Structures can be raised to any height on new fill. However, the extent of raising on walls or columns is limited by foundation stability. Six feet is generally considered an upper limit for this means although some residences have been raised satisfactorily by as much as nine feet.

### Caution

Raising a structure does not eliminate the need for evacuation during floods. Remaining in an elevated structure can result in being trapped. The possibility also exists that the structure's supporting system may fail due to erosion or battering by debris.

The appearance of a structure or its neighborhood may be adversely affected by raising. However, this can often be mitigated by landscaping and/or adjustment of ground levels around the structure.

## Economic Considerations

Raising a structure reduces damage caused by flood heights below the new first floor elevation. Some damage may still take place from higher floods. Basement damages and damages to outside property are not reduced.

The major costs for raising an existing structure are those for:

- Bracing, jacking and resetting the structure.
- Disconnecting, extending and reconnecting utilities.
- Extending the existing foundation or constructing a new foundation.
- Reconstructing walks, steps and ramps.
- Relandscaping.

Depending on site conditions and other circumstances, additional cost may be involved for:

- Removal and disposal of sidewalks, curbs, ramps and driveways not used in the reconstruction.
- Updating the structure foundation and utilities to code.
- Additional bracing for stucco, brick sidings or structures in poor condition.
- Reconstruction of chimney and fireplace.
- Temporary housing and storage of contents during raising.

Many of the costs are independent of the height of raising. Elevating a structure six feet is therefore only slightly more expensive than raising it some lesser amount.

## Elevating New Structures

The object of this measure is to design and construct buildings with

their damageable portions above flood level.

## Description

New buildings may be constructed with their damageable portions above anticipated flood levels using either earth fill or supporting members.

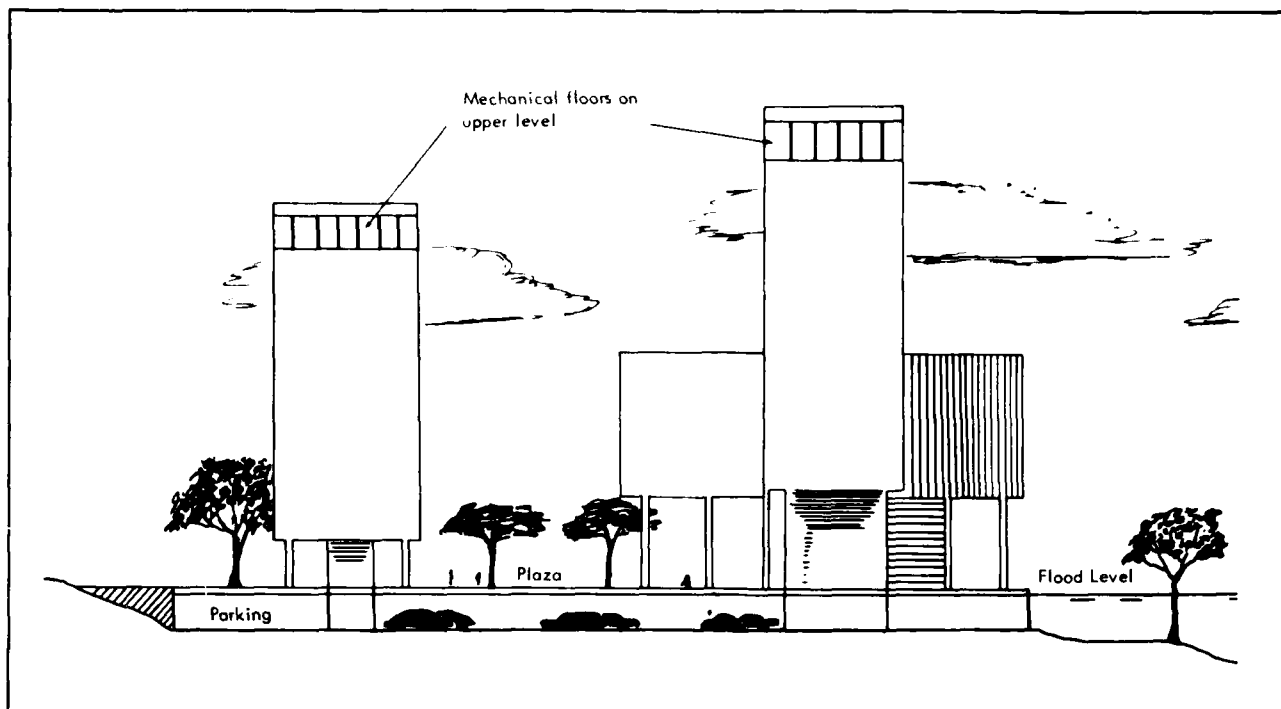
Earth fill is commonly used for elevating residential subdivisions, shopping centers, industrial parks, and individual structures. It is well suited for use over large areas because it enables elevating utilities, roads and storage areas as well as the structure to be protected. Another advantage is that earth fill can be placed and contoured in a manner which harmonizes with the natural terrain. Care must be taken in placing an earth fill to avoid deflecting floodwaters onto adjacent properties or otherwise increasing flood problems for others.



*Elevation above flood levels is easily combined with good architectural design in new structures.*

Supporting members including columns, posts and piles are often used to elevate residential, commercial and industrial structures. The supporting members can often be incorporated into the building design in such a way as to provide a striking appearance.





*Elevation of buildings can help avoid flood damages while providing an attractive architectural design.*

Open spaces under elevated buildings are frequently used for parking or, in the case of commercial buildings, made into decorative areas by the addition of benches, fountains and other features. Ground level space can be enclosed to provide weathertight storage or a garage. However, any wall panels or other provisions for enclosure are usually designed to fail or be removed during floods in order to reduce resistance to flow.

### **Applicable Types of Structures**

Elevation of new structures on either earth fill or supporting members is applicable to various residential, commercial and industrial structures. Depending on the structures intended use, elevation may require inclusion of an elevator or limit access to the building. Access problems may be particularly important to businesses with extensive shipping and receiving operations.

### **Limitations**

There are no significant physical limitations on the use of supporting members for elevation other than the capability of the underlying ground to support the loads involved. However, foundations can be designed and constructed to accommodate most soil conditions. As a result, the use and height of supporting members is most often determined by architectural considerations.

The principal factors which limit the use and height of earth fills for new structures are:

- Availability of adequate amounts of earth from a nearby location.
- Capability of the natural earth at the site to support the weight of the fill and the structure.
- Availability of adequate space and suitable topography to blend the fill to the natural ground conditions.

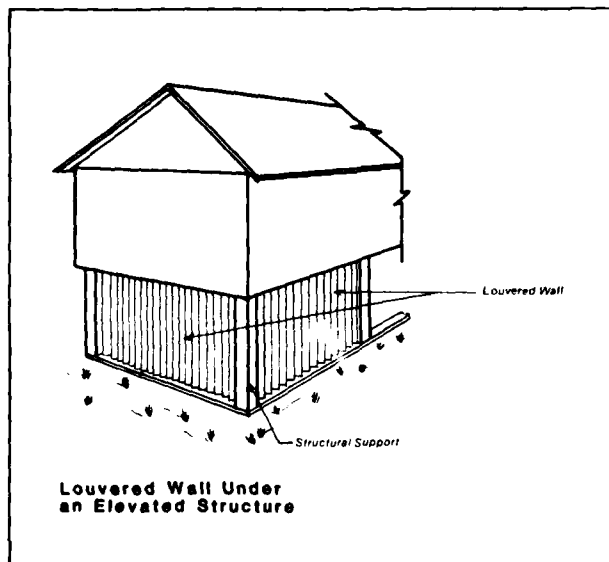
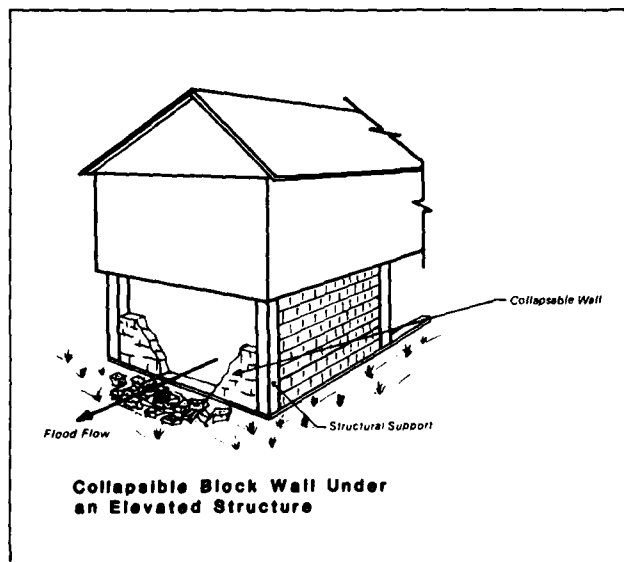
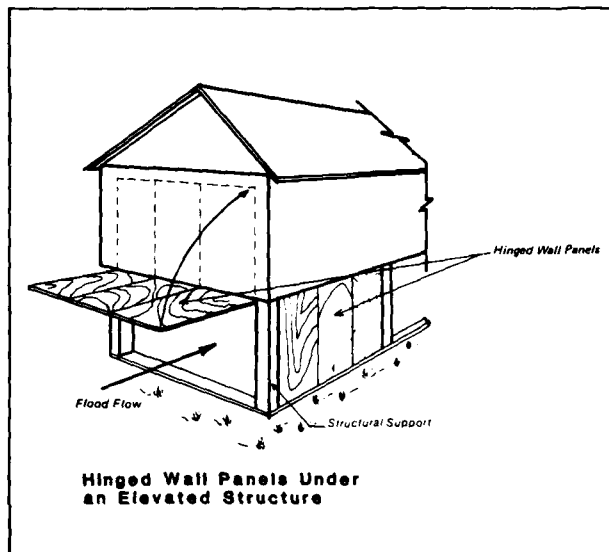
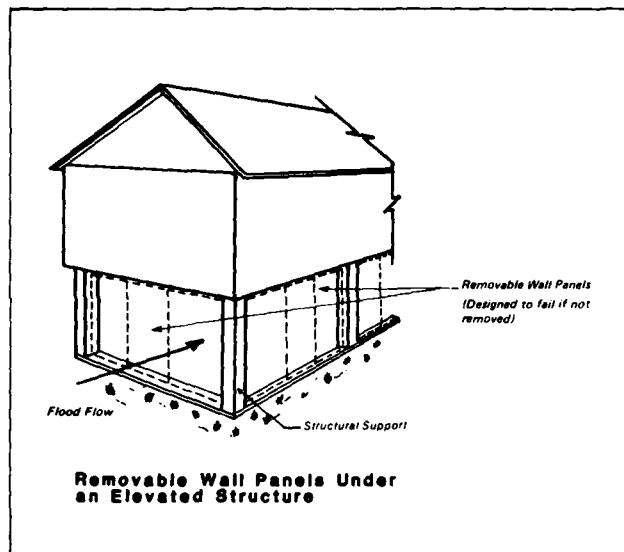
## Economic Considerations

Elevation on earth fill reduces flood damage to utilities, landscaping and other property as well as to the raised structure. Elevation of a building on supporting members reduces damages only to the building.

The cost of elevating a new building is the difference in cost

between constructing it with and without the elevation. The major cost items associated with elevation are those for:

- Fill and/or supporting members.
- Access ramps, stairways and elevators.
- Additional duct work, wiring and plumbing.



The space under elevated buildings can be enclosed in a variety of ways which will limit obstruction of flood flows and reduce the chances of structural failure. Uses of the enclosed area should be limited to those not subject to flood damages.

Depending on circumstances, additional costs may be involved for:

- Flood protection.
- Installation of the underside of the first floor and utilities on structural masonry support members.
- Protection of support members and utilities against damage from debris.

## Small Walls and Levees

The objective of this measure is to prevent entry of water into a structure or other protected area.

### Description

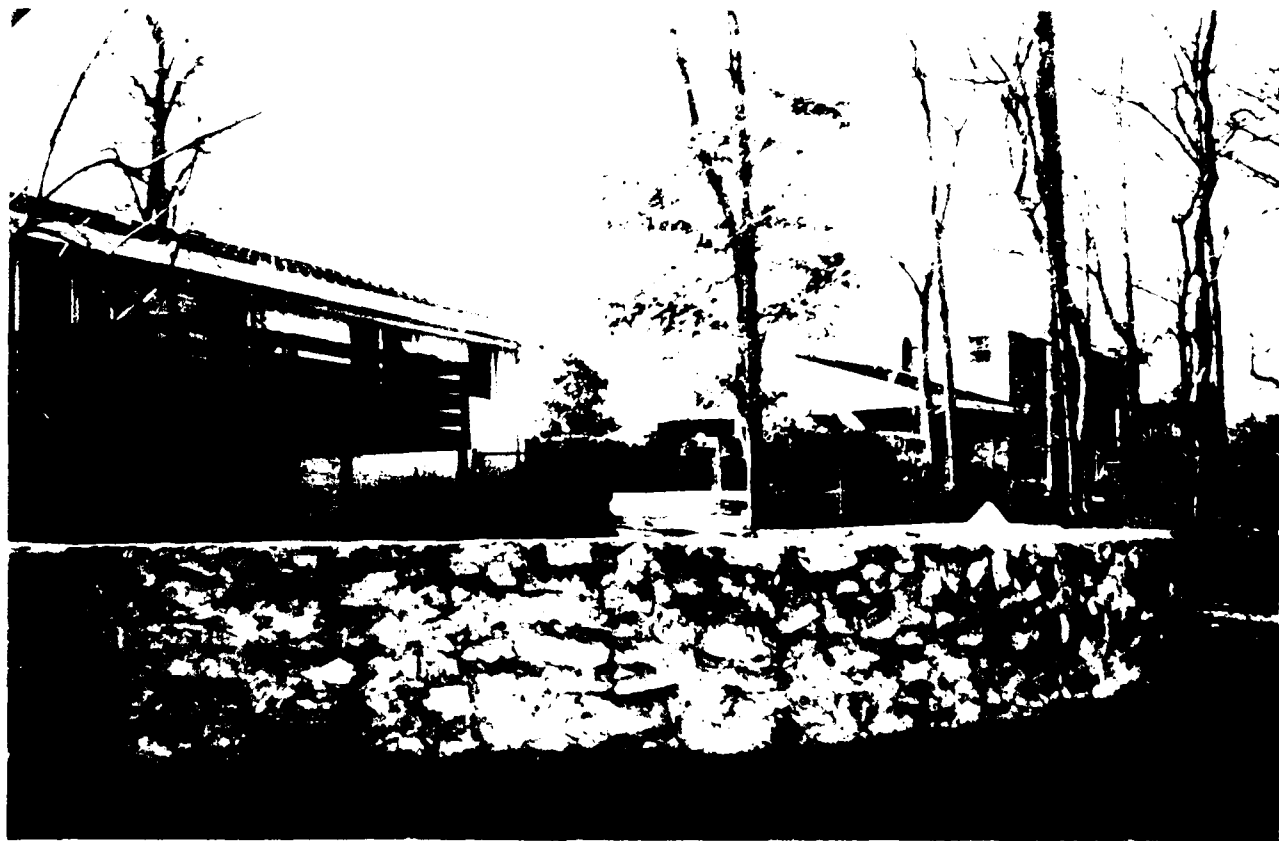
Flood waters can be prevented from entering a structure or other area

by constructing an impermeable barrier around the perimeter of the area. Two common types of barriers are flood walls and levees.

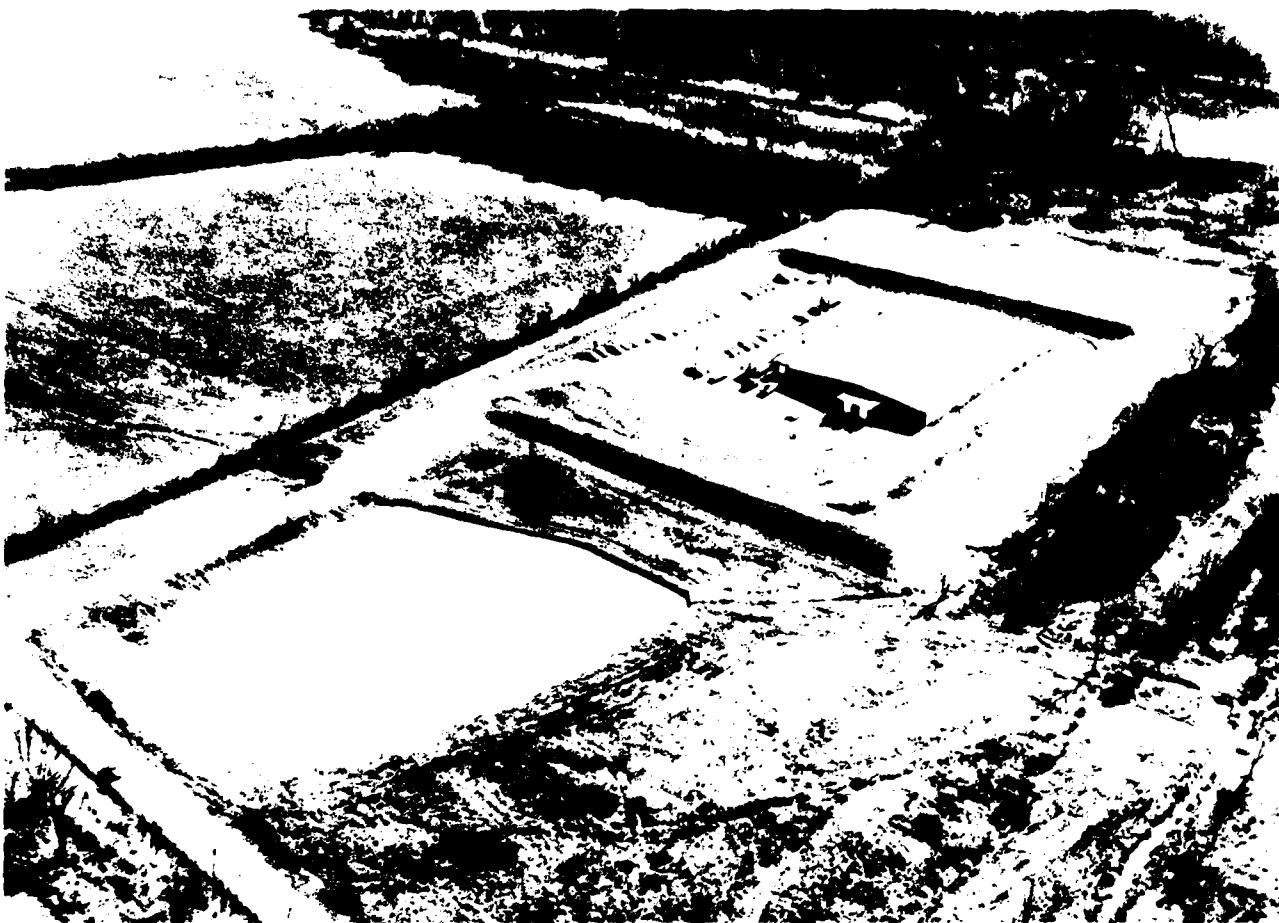
Walls may be constructed of brick, stone, concrete, or other materials. They must be designed to resist the lateral and uplift pressures associated with flooding.

Earth levees are usually constructed with an impervious core to prevent seepage. The side of levees exposed to flood waters must be protected against erosion where high velocities are expected.

Access to areas protected by a low earth levee can be provided by driveways and walks which cross the levee. For higher levees and for walls, an access opening is required which must be sealed during floods using



*Flood damage reduction measures can often be attractively designed. This home in Montana is being protected from flooding by a masonry wall.*



*Small levees provide a relatively inexpensive means of protecting structures and the adjacent grounds. The drive to this protected area uses ramps over the levee.*

shields, sandbags, automatic gates or other techniques. The need to seal access openings and take other contingency action requires advanced flood warnings and personnel available on a 24 hour basis.

Unless a protective wall is built immediately adjacent to a building, precipitation falling within the protected area and seepage into the area can accumulate and cause damage. Therefore a pump located at the lowest part of the protected area is usually needed. The necessary capacity of the pump depends on the anticipated rainfall intensity, size of the protected area and space available for onsite storage of water. An internal drainage system may also be necessary. A

reliable source of power such as a gasoline operated generator or engine must be available for pump operation.

Areas protected by walls and levees are also subject to flooding by sewer lines or storm drain backflow. Thus, anti-backflow valves may be needed.

### **Applicable Types of Property**

One advantage of small walls and levees is their independence from the structure or contents of the area being protected. They can be used to protect residential, commercial and industrial property regardless of size, condition, or type of construction.

Small walls and levees can be designed to suit the property being protected. For example, walls may be used to form a porch front or some other portion of a structure or detached as a property line barrier. Where appropriate, walls can also be used to define patio or garden areas.

Where several properties are located close to one another, a single wall or levee may be used to surround them. If desired, the space within the outer perimeter may be subdivided to create "cells" around each structure, each with its own system for internal drainage. This makes the protection of each area independent in operation.

## Limitations

The principal physical factors affecting the use of small walls and levees are depth of flooding, available space, and soil conditions.

Walls and levees of considerable height can be designed. However, cost, esthetics, and other factors usually limit their height to about six feet. They are therefore only useful in protecting against flood depths of four to five feet if a margin of safety is provided against waves. Wall and levee heights may be limited in urban areas to avoid hiding storefronts, obstructing access for fire fighting, or to comply with zoning ordinances.

Reinforced concrete walls can be made relatively thin to fit between structures or to avoid obstructing use of the protected area. However, small levees may have a top width of up to several feet and flat side slopes which spread several feet horizontally for each foot of height. Therefore, a levee six feet high may have an overall width of up to 40 feet. This width makes levees generally unsuitable for use in densely developed commercial and residential areas.

The soils at the site must be capable of supporting both the weight of the wall or levee and the loads transmitted to its foundation. The soil

must also be impermeable enough to prevent excessive seepage which could flood the protected area or undermine the wall or levee.

Soil conditions are particularly important if the protected area includes buildings with basements. Porous soils which become saturated either from underground seepage or rain falling within the protected area can flood basements or create large hydrostatic pressures on basement walls. Strengthening and sealing of basement walls and floors may be required in such cases.

### Caution

Walls and levees require professional design and construction if they are to successfully resist flood forces. Professional assistance should be obtained for investigating and dealing with potential problems of seepage, drainage and saturated soils.

Walls and levees may or may not detract from a property's appearance, depending on design and construction. Appearance can be improved by using alignments which follow natural ground contours, facing surfaces with attractive materials and landscaping. Care must be taken to avoid increasing damages to adjacent unprotected properties by deflecting or unduly blocking the passage of flood waters.

### Caution

Protection of a structure with a small wall or levee does not eliminate the need for evacuation during floods. Remaining in the structure may result in being trapped and exposure to serious hazard in the event the barrier fails or is overtopped by higher than anticipated flood levels.

## Economic Considerations

Small walls and levees reduce damages to all of the enclosed property so long as their design level is not exceeded. Damages are not reduced if floods exceed wall or levee height.

The major items of cost associated with a small wall or levee are:

- Construction of the wall or levee and its foundation.
- Provision of access closures.
- Provision for internal drainage.

Protection against sewer back-up.

- Any needed modifications to basements of structures.

Except where basements must be reconstructed, overall costs are usually dominated by the expense of wall or levee construction. Construction costs depend primarily on the length and height of the wall or levee and on the need for special foundation treatment.

Certain basic costs such as those for foundation and drainage work must be done regardless of wall or levee height. As a result, the cost for higher walls and levees tend to be less per foot of height than for lower walls and levees.

Levees are usually less expensive than concrete or brick walls, providing the earth necessary for their construction is available onsite or nearby. However, the opposite may be true if levees must be armored to prevent erosion, complex access openings must be designed or land must be purchased to accommodate a levee's width.

## Permanent Relocation

The objective of permanent relocation is to move damageable property to a flood-free location.

## Description

Three general options are available for permanent relocation:

- Relocation of both a structure and its contents.
- Relocation of only the structure's contents and conversion of the structure to a use compatible with the flood hazard.
- Relocation of contents only and demolition of the structure.

Relocation of a structure and its contents requires that a new site be available. This usually involves acquisition of land and construction of a new foundation. In cases where several structures are to be relocated, it may also require provision of utility services and streets. The structure must be emptied of its contents, moved to the new site, and reset on the new foundation. Provisions must be made during the process for temporary storage and transport of contents and, in the case of a residence, for temporary lodging of residents. Usually the vacated site must be cleared, the foundation removed and basement backfilled. When relocations are undertaken as a public project, vacated lots are frequently maintained in public ownership and converted to park or playground use. This entails a continuing responsibility for management.

Relocation of a structure's contents and reuse of the structure requires that a suitable alternative building be available to receive the contents. The alternative building may be one already existing and vacant or one constructed especially for the purpose. Construction of a building may require construction or installation of streets, utilities and other supporting services. The type of use which can be made of the flood-prone structure depends on its nature and ownership.

Relocation of contents and demolition of the existing structure also requires the availability or

construction of a suitable alternative building. As in the case of relocating both the structure and contents, it often results in conversion of the vacated lands to public ownership.

## **Applicable Types of Property**

Most types and sizes of structures can be moved either in one piece or in segments. However, certain types of structures are more difficult and therefore more expensive to move. The buildings most favorable for relocation are wood frame structures which are:

- Located on a crawl space or basement providing easy access to floor joists.
- Light enough to be raised with ordinary house moving equipment.
- Small enough to be moved without partitioning.

Structures of brick, concrete or masonry over crawl spaces and basements can also be moved but precautions must be taken to prevent excessive cracking. Structures with slab-on-grade foundations pose special problems because of the difficulty of getting lift supports under the structure, the danger of cracking the slab, and the problems of placing the structure on a new foundation. Relocation of structures built on slabs is therefore generally considered to be infeasible. Row houses and apartments pose similar problems.

Commercial and industrial buildings are often large heavy structures built with a slab-on-grade foundation. As a result, relocation of commercial and industrial structures is seldom practical or economical. If the structure cannot be protected by closure of openings or by a small wall or levee, it is usually more economical to remove the contents and find a new use for the structure which is less vulnerable to flood losses. Industrial buildings with metal walls and supports can be disassembled and reassembled on new site.

## **Limitations**

The principal limitations to permanent relocation, aside from physical practicality, is the availability of a suitable alternative site. Some activities are dependent on site-specific resources or characteristics. This includes such things as convenience to shopping or work for residences, dependence on a downtown location for retail businesses, or access to rail or dock facilities for an industry. Alternative flood-free sites which duplicate the desirable aspects of existing sites may be difficult to locate.

In some cases it may be necessary to cross political boundaries to find suitable alternative sites. Relocation of several structures from a small community may have a discernible effect on the tax base.

Residences and other structures located on floodplains are often older in age and style than those in areas where sites are available for relocation. Interspersing older structures among newer structures may adversely affect the appearance of their new neighborhood. Vacated sites may become unattractive if not properly maintained. Relocation of residences also involves relocation of their occupants. This may create substantial social problems.

## **Economic Considerations**

Relocation of a structure to a flood-free site or removal of contents and structure demolition avoids all future flood losses except those associated with the new use of the vacated land. The remaining loss potential is usually small if the land is converted to park or another open space use.

Relocation of contents and change in use of the structure does not eliminate flood damages to the structure. Depending on the new use, the potential for content damage may not be wholly eliminated.

Relocation of contents only and abandonment or demolition of the building is so expensive that it is usually only undertaken as a public project. Even then, it usually is not economically feasible unless some beneficial use can be made of the vacated land. Where projects of this type are undertaken, the major costs are those for:

- Acquiring the existing property.
- Relocation assistance to occupants.
- Conversion of the acquired property to its new use.
- Continuing management of the acquired property.

Acquisition costs depend upon the conditions agreed to between the original property owner and the public body or private party sponsoring the project. These are arrived at through negotiation or condemnation proceedings. Relocation assistance includes such things as payments to offset the seller's cost of finding suitable new property and moving expenses. The major costs for converting the acquired property to its new use are those for structure demolition, landscaping and installation of whatever equipment and facilities are required. Continuing costs include those for operation and maintenance, police protection, etc.

Relocation of contents and reuse of a structure in a way compatible with the flood hazard is more likely to be undertaken as a private measure. It is limited primarily to industrial and commercial structures which can be converted to storage areas for items which either are not vulnerable to flood damage or which can be rapidly evacuated when a flood occurs. The principal costs associated with this technique are for:

- Acquisition or construction of an alternative structure.
- Movement of contents to the new structure.

- Modification of the original structure to suit its new use.

Relocation of both structures and contents is most often done in the case of residential structures since commercial and industrial buildings tend to be unsuited for moving. The measure can be done either unilaterally by the property owner or as a governmental project. In either event, the major costs are for:

- Acquisition or construction of an alternative structure, including installation of necessary services and utilities.
- Moving the structure to the new site.
- Moving the contents to the new site.
- Disposition or management of the vacated site.

## **Rearrangement and Modification of Contents and Facilities**

The objective of this category of protective actions is to reduce damages by rearranging and modifying contents and facilities.

### **Description**

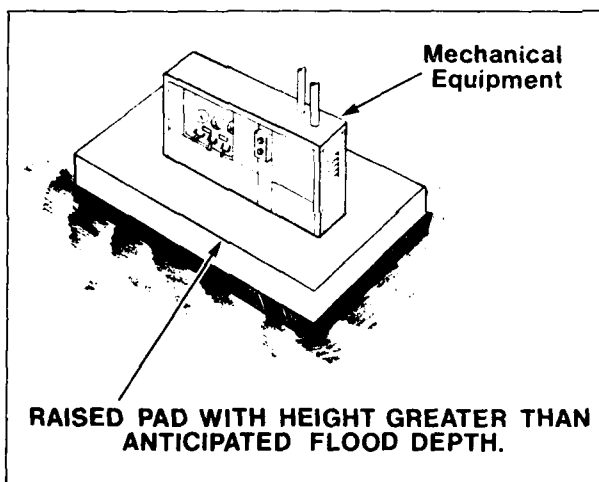
Flood losses to damageable property and interruptions to business activities can be reduced through a wide variety of minor adjustments including:

- Raising damageable building contents above flood levels.
- Elevating all or portions of a structure's service systems above flood levels.
- Constructing "utility cells" or "utility additions".
- Relocating damageable contents to a flood-free site.



- Protecting property from flotation.
- Modifying business operations and procedures.

The exact placement of a building's contents is often flexible. For example, items such as furnaces, water heaters and appliances can sometimes be raised to a higher elevation within a residence or manufacturing equipment can be raised within an industrial building. The extent of possible raising depends on the type of structure and item being considered. Two story buildings and buildings with basements offer the obvious opportunity to shift items to a higher floor level. Where that is not possible or where it is unnecessary because only shallow flooding is anticipated, damageable property can often be raised on pedestals or pads.

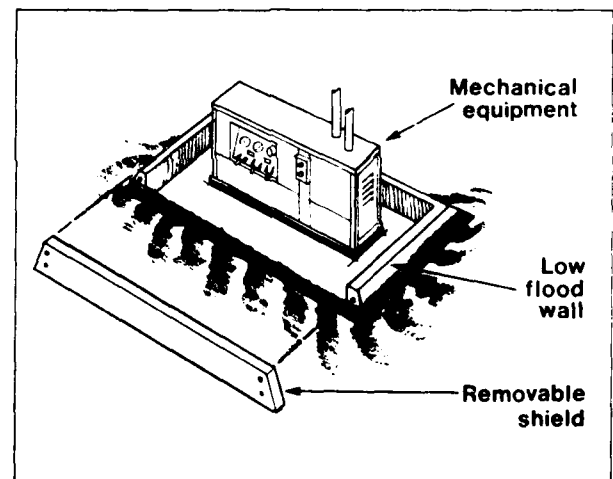


*Furnaces, water heaters, industrial equipment and other items can sometimes be protected against shallow flooding by placing them on raised pads.*

Rearrangement of a building's contents may require modifications in electrical, plumbing, heating or other service systems. Where space is limited, it may also involve an exchange of space in which items which are less vulnerable to flood damage or less expensive are moved to a lower elevation.

Damage to a structure's electrical system is sometimes a substantial portion of overall damage, especially in the case of industrial properties. In addition, inundation of the electrical system poses a significant hazard. Fuse or circuit boxes in homes are often located in basements or other areas subject to flooding, making it difficult to curtail power before reentering a structure. These sorts of problems can be mitigated by elevating wiring, switch boxes and other electrical components. In cases where the whole electrical system cannot be elevated, it can sometimes be modified so as to enable easy and safe curtailment of power in flood-prone areas of the building. Systems can often be divided to enable curtailing power to lower levels while continuing to supply power through an elevated circuit for emergency lighting and other vital functions. Another possibility is the use of electrical "quick disconnects" to enable fast removal of motors and other equipment.

Damages to air ducts can be minimized by raising them above flood levels. Where this is impractical, ducts can be sloped to promote rapid drainage. Any low spots in the system can be prepared for easy drainage by installation of a valve or by punching holes and covering them with tape which will loosen when wetted.

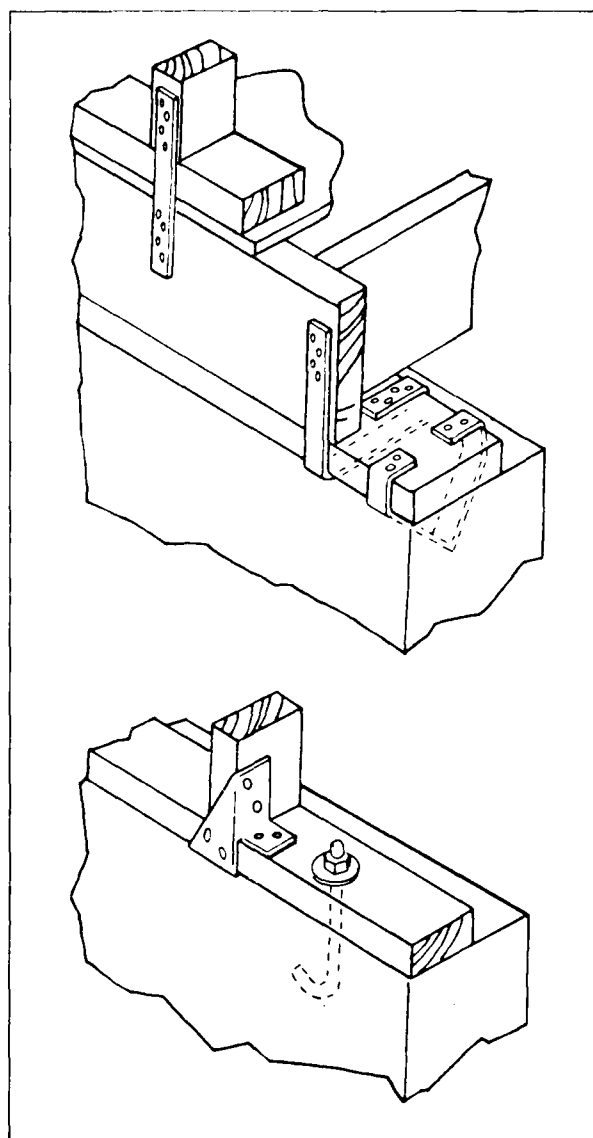


*Portions of areas subject to shallow flooding can be kept dry by building a low wall.*

Flood losses can sometimes be reduced by providing a waterproof cell in the basement to protect utilities. Items associated with this alternative include: concrete, reinforcing, water-stop, watertight door, electrical work, relocation of equipment, and check valves. Alternatively, a new utility room can sometimes be added onto the existing house at the first floor level. Items associated with this alternative include: excavation and backfilling the foundation, superstructure framing, siding and roofing, doors, windows, gutters and painting, electrical work, relocation of equipment, and check valves.

Flood damages may also be reduced by selectively relocating building contents to a flood-free site. Particularly in the case of industrial complexes which include some lands or buildings not subject to flooding, opportunities may exist to move valuable equipment to a safe location. Where space is at a premium, exchanges of space may be practical. For instance, finished products could be stored at a higher elevation and lower lying storage areas used for less valuable raw materials.

Most structures and/or properties contain some items subject to damage by flotation such as propane or other closed tanks, raw lumber or items made of wood, and items which can entrap air such as appliances. Such property can be damaged or even lost when floated as well as damaging the structure enclosing them or downstream structures. Some types of losses due to flotation may be reduced by anchoring items or taking steps to reduce their buoyancy. Anchoring of items, such as fuel tanks, is usually done by bolting or cabling them to heavy concrete anchors or bases. Items which cannot be fixed in place, such as lumber, can be temporarily tied down or enclosed in a structure sufficiently strong to resist flood forces. Buoyancy can be reduced by keeping tanks filled, replacing light contents with heavier ones, and installing vents to release trapped air. Similar adjustments can be made to structures to improve their resistance



*Anchoring of structures to their foundations helps prevent flotation or lateral displacement.*

to flotation. Among others, these include anchoring of buildings to their foundation and providing air vents between floors and under roof areas.

Modifications of operating procedures can sometimes reduce flood losses by enabling at least some business activities to continue during or soon after a flood. For example, stockpiles of raw materials might be maintained to guard against delivery delays.

## **Applicable Types of Structures**

Almost all structures offer the possibility of minor adjustments to reduce flood losses regardless of the structure type or use. Opportunities are generally greater in multi-story structures and multi-building complexes due to greater flexibility for rearrangement of space. Many types of modifications are more applicable to industrial structures where wiring, air ducts and other services are exposed for easy accessibility and where high equipment values justify the expense.

## **Limitations**

The degree to which minor adjustments and modifications of the type described can be used is site specific. It depends on the depth and frequency of anticipated flooding, the value and mobility of equipment, availability of flood-free space and numerous other factors. The only general limitations are those related to cost, convenience and appearance.

## **Economic Considerations**

No general guide to economic feasibility is available for minor adjustments and modifications of the type described since they are site dependent and vary greatly in cost and effect. Each adjustment or set of adjustments must be evaluated independently.

## **Temporary Relocation of Building Contents**

The objective of this measure is to protect items from damage by moving them temporarily to a safe location during a flood.

## **Description**

Some items can be protected from damage by removing them from their

normal place for the flood's duration. The general types of relocation which can be undertaken include:

- Stacking of more expensive items on top of less expensive items or on items not vulnerable to flood damage.
- Raising items on blocks or other temporary supports.
- Moving items to an upper story.
- Transporting items to a location outside the flooded area.

Temporary relocation is applicable to building contents which are vulnerable to flood damage, relatively easy to move, and sufficiently valuable to warrant the expense of movement. Typical types of items to be considered for relocation include household goods, vehicles, small equipment and motors, raw and finished products, business machines, data processing equipment, computer tapes, business records and documents. The general steps involved in temporary relocation include:

- Preparation for rapid removal of items.
- Removal, transportation and storage of items.
- Return and reinstallation of items.

The extent and complexity of necessary pre-flood preparations depends on the type of relocation to be carried out. If items are to be stacked, little planning or advance preparation is necessary except some consideration as to items requiring movement and stability of the items after stacking. Planning for movement of contents to an upper story requires consideration of additional matters such as the availability of adequate space, width of doors and stairs, and capability of upper floors to support the additional load. If furniture, appliances, manufacturing equipment and other contents are to be blocked up in place or moved from the structure, attention must be given to such things

as availability of materials, means of transportation, an area for storage, and labor required for moving the items.

Temporary relocation of residential contents can often be done with little advance preparation. Labor is usually available from friends and family and sorting out items during replacement poses no problem. Storage is often available in the home of a friend or relative and communities sometimes make schools or other buildings available for this purpose. Items can also be stored temporarily in trucks or rental trailers.

Preparation for relocation of items is more important and complex in the case of a commercial structure or large public building because of the values and amounts of contents involved. Preparations may need to address the priority in which items will be protected and assure the availability of necessary labor, transportation and storage areas. In frequently flooded areas, preparations may include such things as adding wheels to display counters to facilitate quick movement of goods. Identifying file drawers for priority evacuation is also useful.

Industries often present a still more difficult situation for temporary relocation because valuable equipment is often heavy, bulky, and connected in place with wiring or plumbing. Preliminary preparations may need to include such things as:

- Establishing a plan identifying the priority for relocating items.
- Modifying equipment to enable rapid disconnection of motors, pumps and other items to be relocated.
- Arranging for trucks and labor to be available.
- Arranging storage areas.
- Marking parts or items to facilitate their proper reinstallation.

## **Applicable Types of Property**

Temporary relocation of contents is generally applicable to all types of structures regardless of type or use.

## **Limitations**

Most problems associated with temporary relocation such as availability of labor, means of transportation, and storage, can be solved through advance planning. The major limitation on the measure's success is the availability of adequate time. Relocations must be completed before routes from the area become impassable. Reliable advance warning of impending floods is essential.

The length of advance warning necessary depends on the time required to assemble the necessary labor and equipment and carry out whatever relocation is to be done. The warning time required can be modified by detailed pre-flood preparations, the amount of labor used and other factors. Relocations can also be initiated before the occurrence of a flood is certain but this involves some risk of unnecessary effort and expense in the event the anticipated level of flooding does not materialize. The risk can sometimes be minimized by focussing early relocation efforts on activities which require considerable time to accomplish but which involve little expense or disruption.

## **Economic Considerations**

The economic feasibility of temporarily relocating an item depends on its value, the potential loss or damage, and the cost of relocation. This must normally be considered on an item by item basis or for classes of items. Evaluation of the potential cost of not relocating an item must include the effect of its loss on overall operations. For example, unavailability of some critical item of equipment which prevents early resumption of production may result in business losses far greater than the value of the item.

Costs for relocating and storing property to avoid flood damage are covered by federal flood insurance.

## Recovery Arrangements

The objective of this measure is to reduce flood losses by appropriate action in the immediate post-flood period.

## Description

The total loss resulting from a flood may sometimes be influenced to a significant extent by the nature of recovery efforts undertaken in the immediate post-flood period. The principal actions which can be taken to reduce potential losses are:

- Documentation of damage for insurance, tax and other purposes.

- Prompt efforts for cleanup, repair and salvage.

### Caution

A careful examination should be made before entering a structure which has been flooded to ensure it is not in danger of collapse and that gas and electric service is discontinued. Even when switched off, electric circuits may be energized due to shorting by water and/or debris. Caution must also be taken in pumping basements. Too rapid lowering of the water level can cause walls to collapse or floors to buckle.

The net loss to the owner or operator of a flooded structure is reduced through insurance payments and tax credits for the casualty loss.



Anything on the floodplain which is not anchored may be swept away by a flood or become debris. Large items, such as this mobile home, may collide with and damage downstream bridges or other structures or may block bridges and raise flood level.

Costs other than those covered by the above should be identified for reimbursement. For example, the expenses of a temporary relocation of a firm's operations in response to an environmental emergency, including damage to the firm's reputation due to a spill, should be reimbursable. The National Flood Insurance Program, All costs associated with emergency action should be reimbursed and itemized as such in the disaster claim. Floods provide a good test case for claims, where the operator of a commercial and industrial property that which extensive emergency actions are undertaken may find it advantageous to establish special accounting matters to identify emergency costs.

Certain types of damages or losses continue to increase after flood waters have receded. These include physical damages due to water, debris,



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nation, mildew, and rot, and business losses due to lost sales or suspended production. Such losses can be minimized by prompt action to clean up the property, salvage damaged items and restore operations.

Cleanup of flooded structures involves removal of water, sediment and debris. This usually requires pumps, hoses and other equipment which may not be ordinarily kept on hand and which will be in short supply after a flood. Advance preparation for recovery efforts may therefore need to include stockpiling of such items. Other supplies or parts may need to be kept on hand to recondition or replace components of the structure's electrical and other systems, decontaminate water supplies or repair equipment. Independent sources of electrical power to operate emergency lights and pumps may also be needed.

Salvaging of furniture, carpets, office equipment and other contents of flooded structures is primarily dependent on quick drying and other treatment to prevent deterioration. Fans, water displacement solutions, lubricants, dehumidifiers and heaters are usually required.

Restoration of operations for commercial and industrial properties may require repair or replacement of equipment, overcoming transportation problems caused by the flood, or shift-

ing of activities to new locations. Rapid solution of these kinds of problems requires advance consideration of damages which could potentially result from a flood as a basis for stockpiling spare equipment and materials, development of alternative operational procedures and other arrangements.

## **Applicable Types of Property**

The advance development of recovery arrangements is generally applicable to all kinds of property regardless of structure type or use. It tends to be more important for commercial and industrial operations because of the potential for large losses due to interruption of business.

## **Limitations**

There are no inherent limitations on the use of recovery arrangements.

## **Economic Considerations**

The cost and benefit of recovery arrangements are site specific and depend on their nature and that of the property at risk. However, most types of recovery arrangements are sufficiently inexpensive so at least some are likely to prove economical for any property subject to flooding.

# Chapter 4

## COMMUNITY ADJUSTMENTS

A wide variety of actions may be taken by communities to reduce flood losses. At least some are applicable to every situation. Comprehensive programs combining use of several measures are usually the most effective.

Community adjustments to flooding are measures dealing with flood problems on an areawide or community-wide basis and requiring local government's participation in their planning, implementation, operation and maintenance. The principal community

adjustments to flooding are:

- Land use control.
- Flood warning systems and preparedness measures including flood fighting.
- Major public works.



*Communities have historically located near rivers, lake shores or sea coasts. This has created a national flood problem of massive proportions.*



Table 2 summarizes community adjustment measures with respect to purpose, applicability and economic feasibility.

## Land Use Control

The objective of land use control is to limit the uses of flood-prone lands to those commensurate with the flood hazard.

## Description

There are numerous reasons to control the use of flood-prone lands. Among the most important of these are to:

- Require prudent land use and avoid new developments which will be subject to damage and/or pose safety problems for those working or living there.
- Prohibit buildings, land fills and other developments which will reduce the space available for passage of floods, thereby raising flood levels and increasing upstream damages.

- Prevent victimization and fraud of unwary buyers in the sale of flood-prone lands.



*Low bridges, land fills and structures interfere with flood flows and may increase upstream flood depths.*

TABLE 2  
SUMMARY OF COMMUNITY ADJUSTMENTS TO FLOODING

Adjustment	Purposes	Applicability	Economic Feasibility
Land Use Control	Prevent unwise development in flood hazard areas.	Applicable to all streams and all sources and causes of flooding. Most applicable to areas not yet fully developed.	Required by National Flood Insurance Program and some state statutes. Seldom subjected to economic analysis.
Flood Warning and Preparedness	Provide early warning of impending floods and take prompt actions to improve safety and reduce damages.	Applicable to nearly all streams and all degrees and types of development.	Basic systems tend to have small cost and be feasible by large margin but may leave large residual damages. Sophisticated systems usually feasible for developed areas.
Major Public Works	Reduce peak flow of floods, reduce flood elevations, contain flood flows within channel, or route flood away from developed areas.	Varies by type of public works, and causes, nature and size of flood source. Most applicable for protection of urban areas.	Economic feasibility is often marginal unless measure serves other beneficial public purposes. Generally restricted to protection of valuable property.

- Prevent the development of situations which may require extraordinary community expenses for emergency services, construction of flood control works or other actions to mitigate flood problems.

There are techniques for acquiring an interest in land at little or no cost such as conservation easements and gifts. Communities often purchase flood-prone lands for use as parks, athletic fields, golf courses, nature preserves or other purposes not vulnerable to large losses from floods. To spread the financial requirements over time, some communities acquire parcels on an individual basis as they are offered for sale. Other communities have acted in the period following a severe flood to acquire and clear damaged properties. States, conservation groups, universities and other organizations may also be interested in buying flood-prone lands for open space uses.

Controlling land use through regulations is possible. In most states, legislatures have delegated regulatory authority to local governments. Some states mandate local control over the use of identified flood-prone lands. The principal types of regulations used are zoning, subdivision regulations, building codes, housing codes, and sanitary and well codes. Controls for floodplain management may be incorporated into regulatory programs for other purposes<sup>9</sup> or drafted as single purpose ordinances.

Zoning divides a government unit into specified areas for the purpose of regulating the use of structures and land, the height and bulk of structures, the size of lots and density of use. Zoning may be used to set special standards for land uses in flood hazard areas including specification of minimum floor elevations. Floodplain zoning programs often divide the area

being regulated into districts according to the degree of flood risk and the stringency of applicable regulatory controls. Programs may be single district, two-district, or multi-district. Single and two-district programs are the most common.

Administration of riverine floodplain zoning ordinances is simplified by the designation of floodway or floodplain encroachment limits. Floodway limits are designated so that any development permitted in the remainder of the floodplain (i.e., within the flood fringe) will not result in an increase in flood height over a



Urban floodplains can be acquired and converted to parks, open space or other uses not subject to large flood damages. This park is located along Indian Bend Wash in Scottsdale, Arizona. Equipment in the park is either anchored or removable to reduce losses.

<sup>9</sup>The following description of specific regulatory tools is adapted from The Unified National Program for Flood Plain Management.

prescribed amount for a specific frequency flood at any location along the stream. Usually, the allowable increase in flood height is one foot or less while the specific frequency flood is usually the flood having a one percent chance of being exceeded in any given year.

Although the floodway concept does not apply in coastal areas, there is a parallel for high hazard coastal and lakeshore areas where the major forces of tides and waves come into play and where the erosional changes are at a maximum during flooding. The coastal area maps prepared by the National Flood Insurance Program identify such areas as "coastal high hazard areas."

Subdivision regulations guide the division of large parcels of land into smaller lots for the purpose of sale. Often the community's jurisdiction is extended beyond its boundaries by subdivision-enabling legislation. Such extension provides control usually unavailable through zoning.

Subdivision regulations help to assure that lots are suitable for their intended use without putting a disproportionate burden on the community. They also control improvements such as roads, sewers, water, and recreation areas. Subdivision regulations often require:

- Showing the location of flood hazard areas on the plat.
- Avoiding encroachment into floodplain areas.
- Determining the most appropriate means of elevating a building above the regulatory flood height.
- Installing adequate facilities for drainage and stormwater management.
- Placing streets and public utilities relative to the selected flood protection elevation.

Building codes regulate neither the location nor the type of develop-

ment; rather, they control building design and use of construction materials. Building codes can reduce flood damages to structures and contents by setting specifications to:

- Require suitable anchorage to prevent flotation of buildings during floods.
- Establish minimum elevations for the lowest floor of structures.
- Require electrical outlets and mechanical equipment to be above regulatory flood levels or to be appropriately floodproofed.
- Restrict use of materials that deteriorate when wetted.
- Require a structural design that can safely withstand the effects of water pressure and flood velocities.

Building codes may also be used to require flood protection for below-ground spaces in areas out of the range of inundation but still within the zone of sewer backup and flood-elevated groundwater. Performance standards for floodproofing are sometimes included in floodplain zoning ordinances rather than in building codes.

Housing codes, like building codes, set minimum standards for construction, but they also set minimum standards for maintenance. These may be used to require repair of flood damaged structures in a manner that will ensure the safety of occupants and prevent blight.

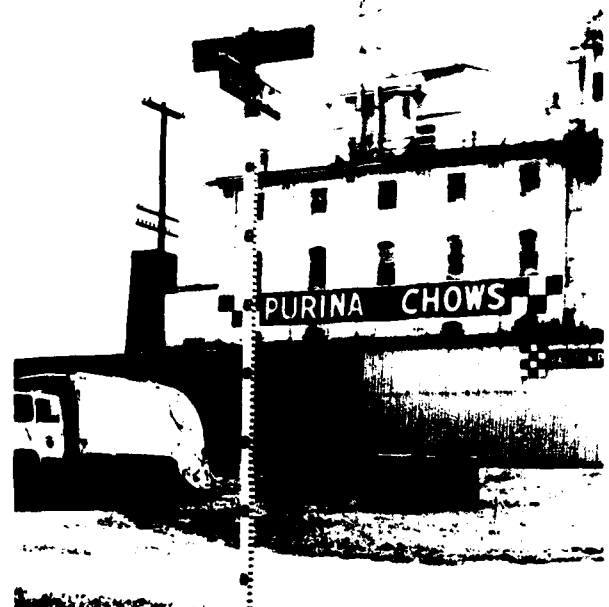
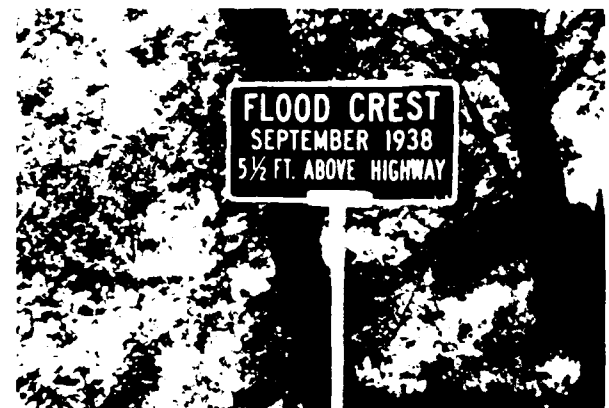
Sanitary and well codes establish minimum standards for waste disposal and water supply. Sanitary codes commonly prohibit the construction of onsite waste disposal facilities such as septic tank systems in high groundwater and flood hazard areas. Requirements for elevation or floodproofing of public sewer systems may also be included. Well codes often establish special floodproofing requirements for facilities located in flood hazard areas to help reduce their potential for contamination.

Use of flood-prone lands can also be influenced by local programs which discourage inappropriate uses or which at least ensure that prospective developers or buyers of land are aware of the flood hazard. Such programs may include the use of any or all of the following:

- Requiring by ordinance that sellers or real estate brokers disclose flood hazards on marketed lands.
- Marking deeds of flood-prone lands to note the hazard.
- Adoption of policies regarding the extension into flood-prone areas of utilities, streets and other services which facilitate or spur development.
- Differential taxation to encourage keeping lands in open space uses.
- Posting of warning signs and or markers delineating historical flood boundaries.
- Conducting a continuing program of information and education to create community awareness of the flood hazard.
- Transfer or purchase of development rights.

## Applicability

Control of land use through acquisition is technically applicable to all lands in private ownership regardless of the extent or type of development. The high cost of developed land usually makes acquisition most practical for land which is either undeveloped or only developed for agriculture or other open space uses. However, there may be opportunities to acquire flood-prone land in conjunction with other programs in developed areas, such as those for waterfront renewal. Also, methods exist for acquiring land or controlling its use which are less costly than outright purchase, e.g., lease, easement, transfer of development rights, etc.



*Warning signs remind the public of the flood hazard and protect unwary buyers of land and homes from being victimized.*

Regulatory measures controlling land use usually exempt existing uses from compliance to avoid imposing undue hardships on property owners as a result of a change in governmental policy. Consequently, these types of programs are of limited value in fully developed areas except as they affect expansion, modification or repair of existing structures. Regulatory measures are most applicable to areas which are undeveloped and if stringently applied, can achieve the purpose of land use control nearly as well as acquisition.

The effectiveness of various measures which discourage unwise development in flood hazard areas decreases as the intensity of development increases. However, all of the measures have some value for use in developed areas.

## Limitations

The principal limitations on controlling land use through acquisition are its cost and its effect of transferring flood problems from private owners to the public. These constraints usually limit acquisition to those cases where public ownership can serve other beneficial public purposes such as for parks.

Regulatory measures for controlling land use are based on the state's police power. Its constitutionality is well established. However, regulatory requirements must meet numerous standards concerning due process and reasonableness. For example, requirements must not be so restrictive as to deprive owners of all economic use of their land. Apart from such legal requirements, the primary limitation on



*In addition to avoiding flood damages, floodplains kept as open space provide relief from urban congestion, a buffer against noise and opportunities for recreation.*

the use of regulations is the need for their continuous administration and enforcement. This can require the full-time services of up to several people, depending on the size of the regulated area, complexity of the program and other circumstances.

## **Economic Considerations**

The principal costs for control of flood-prone lands through acquisition are:

- Purchase of the land or the cost involved in obtaining an interest in management of the land.
- Removal and/or demolition of structures and conversion of the land to its new use if it is currently developed.
- Management of the acquired lands.

The relative size of the costs can vary, depending on the stage of development of the acquired lands. Usually, lands which are acquired are undeveloped and kept in open space use after acquisition. Purchase of the land is the dominant cost in such cases.

Control of land use through regulatory measures involves costs for:

- Delineation of the lands subject to flooding.
- Drafting and adoption of regulations.
- Operation and enforcement of permit regulations.

The largest of these costs is usually for operation and enforcement. Costs for delineation of flood-prone areas and for the drafting and adoption of regulations are paid for largely by federal and state governments. The operation and enforcement cost often depends on the extent to which the community is already involved with other regulatory programs. If other regulatory programs are being

administered, introduction of flood-related regulations may require little in the way of training or additional staff.

The variety of programs for discouraging unwise floodplain use differ too greatly in their nature to enable even general observations about their cost. Each program must be considered individually with respect to its degree of application and requirements.

Analysis of the costs associated with land use control need to consider any loss of productivity on the controlled lands. In some unusual cases, the benefits of floodplain use and the costs of control may be significantly greater than the flood losses which might occur if development were allowed. For example, regulations limiting expansion of an industry may encourage the industry to move or make their expansion at another location. Communities often deal with this problem by enacting regulatory controls which permit development in some flood hazard areas if adequate floodproofing or other protection is provided for the development.

## **Flood Warning and Preparedness**

The objective of flood warning and preparedness is to provide early notification of impending floods and take prompt action to safeguard lives and reduce property damages.

### **Description**

Flood warning systems are based on measurement of precipitation and/or streamflow in upstream areas. The information is used to predict whether a flood will occur, its time of occurrence and its magnitude. Appropriate notices are then issued to the public in the affected area and to officials responsible for implementing flood preparedness plans or taking other protective actions.

Community flood warning and preparedness programs improve safety and reduce damages by enabling:

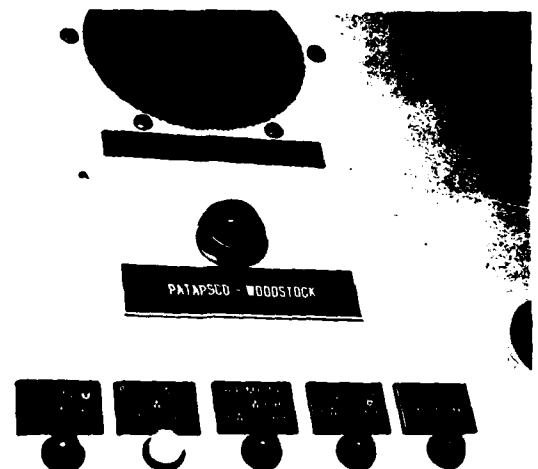
- Timely evacuation to eliminate risks both to evacuees and rescuers.
- Deployment of personnel and equipment to assure continuation of police, fire, medical and other vital services.
- Management of utility systems to minimize damage and creation of secondary problems.
- Temporary relocation, elevation or other protection of moveable property.
- Sandbagging, contingency floodproofing or other actions to protect structures.
- Faster and more complete recovery from floods.

Flood warning and preparedness systems also have other less obvious benefits for communities including:

- Faster and less expensive return to normality.
- Elimination of costs for precautionary actions found later to have been unnecessary.
- Reduced costs for emergency shelter, other care and public assistance for evacuees.
- Reduced liability risks.

The principal components of a local flood warning and preparedness program are the flood recognition system, provisions for warning dissemination, and the preparedness plan containing arrangements for evacuation and other purposes.

Flood recognition systems consist of arrangements and means for collecting the information on which the flood prediction is to be based and for making the prediction. Two basic approaches are available for flood recognition. The one most commonly used



Water level sensors which send a signal to an alarm box can be used to warn of high flows in upstream areas. Many types of sensors are available. The sensor and alarm box may be connected by wire or the signal sent by radio.

is based on measurement of precipitation received in upstream areas. The alternative approach is based on measurement of stream levels upstream of the area to be protected.

Approaches based on measurement of stream levels have the greatest potential accuracy. However, such systems only provide a length of warning time equivalent to the time required for flood waters to travel from the point of measurement to the protected area. Flood recognition systems based on rainfall measurements generally provide longer warning times because of the additional time required for surface runoff to reach streams. The best characteristics of each approach can be combined by basing flood predictions on a system using measurements of both precipitation and stream levels.

Collection of precipitation and stream level data can be done using volunteer observers or automated gages. The best approach for a particular area depends on the availability of persons willing to serve as observers, arrangements which can be made for transmitting data, nature of flooding expected, accuracy desired in the flood predictions, and other factors.

Measurements of precipitation or stream level can be transmitted in a variety of ways. Data collected by observers are usually forwarded by telephone to the system coordinator. Where telephone service is subject to disruption during severe weather, provisions are often made to back up telephone communications with radio using either fixed stations or by dispatching mobile units as needed. Data collected by automatic gages are normally transmitted by radio telemetry or telephone. Collection and transmission of data can also be accomplished via satellite.

Flood predictions based on rainfall measurements are commonly made by averaging the amounts reported from several points in the upstream watershed and then referring to a chart or



*The National Weather Service (NWS) provides assistance to communities in establishing local flood warning systems. Here, a staff member from NWS installs a gage which will radio information on rainfall to a downstream area for use in predicting floods.*

table for the prediction of flood severity. Figures 2 and 3 respectively show the typical types of charts and tables which are used. Flood predictions can also be made using a mathematical model executed on a high speed digital computer. Charts, tables, computer programs and other such aids must be developed specifically for each warning system. National Weather Service (NWS) offices may often provide assistance in preparing such material.

Flood predictions based on stream levels are made by using "crest-stage relationships" which identify the flood elevation to be expected at a point due to some measured stream level upstream. The estimated time of occurrence of the predicted flood level is based on the time required for flood waters to travel between the two points.



Flood predictions are only useful when they reach those persons who need to take some action. These may include public officials, staff of public agencies, managers of various facilities, and the general public located in the threatened area. Different groups of these people may need to be notified depending on the severity, timing or exact location of expected flooding. Arrangements for warning dissemination

must be designed to assure that warning messages reach every person needing the warning regardless of the time of day, location in the area or weather conditions.

Warnings are frequently transmitted to the public by vehicles equipped with sirens and/or public address systems, fixed siren or airhorn systems, radio, and television. These

RAIN	COLUMN NUMBER (VARIES WITH SOIL MOISTURE CONDITIONS)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.00	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11	11	12
1.25	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11	12	12	12
1.50	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11	11	12	12	12	13
1.75	10	10	10	10	10	10	10	10	10	10	10	10	10	11	11	12	12	13	13	14
2.00	10	10	10	10	10	10	10	10	10	10	10	11	11	11	12	12	13	13	14	15
2.25	10	10	10	10	10	10	10	10	10	10	11	11	12	12	12	13	13	14	15	16
2.50	10	10	10	10	10	10	10	10	10	11	11	12	12	12	13	13	14	15	16	17
2.75	10	10	10	10	10	10	10	11	11	11	12	12	12	13	13	14	15	16	17	19
3.00	10	10	10	10	10	10	11	11	11	12	12	12	13	13	14	15	16	17	18	20
3.25	10	10	10	10	11	11	11	12	12	12	12	13	13	14	15	16	17	18	20	21
3.50	10	10	10	11	11	11	12	12	12	12	13	13	14	15	16	17	18	19	21	23
3.75	10	10	11	11	11	12	12	12	12	13	13	14	15	16	17	18	19	21	22	24
4.00	11	11	11	11	12	12	12	13	13	13	14	15	16	17	18	19	20	22	24	25
4.25	11	11	12	12	12	12	13	13	13	14	15	16	16	18	19	20	22	23	25	26
4.50	11	12	12	12	12	13	13	13	14	15	16	16	18	19	20	21	23	24	26	27
4.75	12	12	12	12	13	13	13	14	15	16	16	17	19	20	21	23	24	25	27	28
5.00	12	12	12	13	13	14	14	15	16	16	17	19	20	21	22	24	25	26	28	29
5.25	12	13	13	13	14	14	15	16	16	17	19	20	21	22	24	25	26	27	28	29
5.50	13	13	13	14	14	15	16	16	17	18	20	21	22	23	25	26	27	28	29	30
5.75	13	13	14	14	15	16	16	17	18	20	21	22	23	24	26	27	28	29	30	30
6.00	13	14	14	15	16	16	17	18	20	21	22	23	24	25	26	28	29	29	30	31
6.25	14	14	15	16	17	17	18	19	21	22	23	24	25	26	27	28	29	30	31	32
6.50	15	15	16	17	17	18	19	21	22	23	24	25	26	27	28	29	30	31	31	32
6.75	15	16	17	18	18	19	20	22	23	24	25	26	27	28	29	30	30	31	32	33
7.00	16	17	18	18	19	20	22	23	24	25	26	27	28	29	29	30	31	32	32	33
7.25	17	18	18	19	20	21	23	24	25	26	27	28	28	29	30	31	31	32	33	33
7.50	18	19	19	20	21	22	24	25	25	26	27	28	29	30	30	31	32	33	33	34
7.75	19	19	20	21	22	24	25	25	26	27	28	29	30	30	31	32	32	33	33	34
8.00	20	20	21	22	23	24	25	26	27	28	29	29	30	31	32	32	33	33	34	34
8.25	20	21	22	23	24	25	26	27	28	29	29	30	31	31	32	33	33	34	34	35
8.50	21	22	23	24	25	26	27	28	29	29	30	31	31	32	32	33	33	34	34	35
8.75	22	23	24	25	26	27	28	28	29	30	30	31	32	32	33	33	34	34	35	35
9.00	23	24	25	26	27	28	28	29	30	30	31	32	32	33	33	34	34	35	35	36

Gage height at zero flow - 10 feet  
Bankfull stage - 20 feet  
Time from middle of heavy rain to crest is about 4 hours

INSTRUCTIONS

1. Use column specified by NWS for current conditions.
2. Enter from left with average rainfall.
3. Number in table is stream level (gage) at location in feet.

FIGURE 2. FLOOD FORECASTING TABLE FOR GUADALUPE RIVER AT NEW BRAUNFELS, TEXAS.

Flood stages can be predicted from relatively simple tables. With this table, the local warning system coordinator can use the rainfall amount and the column specified by the National Weather Service to predict the stream level for a particular location.

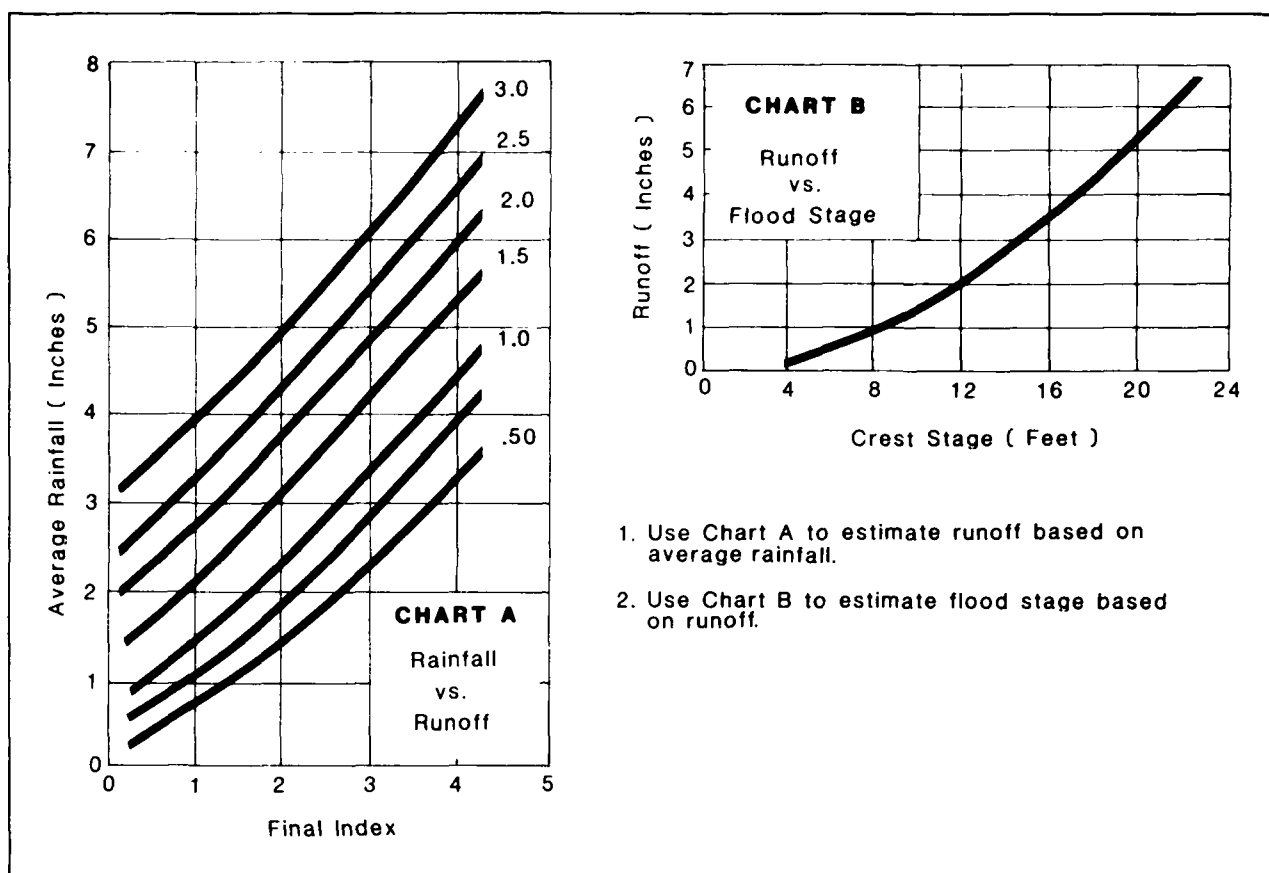


FIGURE 3. FLOOD FORECASTING CHARTS FOR SWATARA CREEK AT HARPERS TAVERN, PENNSYLVANIA

*Flood stages can be predicted from relatively simple charts. The National Weather Service assists in preparing such charts for use in local flood warning systems.*

techniques are sometimes supplemented with door-to-door contact by police, fire, or other personnel. Warnings may also be disseminated by telephone calling arrangements, "block captains" or another system in which selected people are each responsible for notifying a group of others. In-home alarms which can be remotely triggered by radio are also available for use. In addition, announcements can be made over NOAA Weather Radio and the NOAA weather wire, a teletypewriter circuit. Combinations of several or all of these techniques may be employed in a single flood warning program. The decision about which should be used in a particular area depends on several

considerations including availability, number of people to be warned, physical setting, nature of anticipated flooding and desired length of warning time.

The function of a preparedness plan is to guide and coordinate the response to a flood warning. The preparedness plan is important because it provides a large share of the benefits which justify expenditures on the flood recognition system and warning arrangements.

The objectives most often addressed by flood preparedness plans are safety, damage reduction, and reduction of costs other than damages.

Almost all flood preparedness plans place first priority on reduction of the risk to life. Even plans limited to that single objective frequently provide incidental benefits of other types.



*Timely evacuation based on early warnings of floods avoids the need for dangerous rescues.*

Activities included in preparedness plans for safety vary according to the specific needs of the area at risk, the nature of anticipated flooding, and scope of the plan. Evacuation of threatened areas is usually a key measure. Other actions for protection against direct safety threats may include dispersal of medical, fire, police and other emergency services personnel and equipment to assure continued provision of vital services; curtailment of electric and gas service to reduce the risk of fire, explosion and electrocution; and control of toxic or other dangerous materials on the floodplain. Preparedness plans may also safeguard against less direct threats caused by flooding through provisions for vector and disease control and for demolition of unsafe structures in the immediate post-flood period. These measures may be supplemented by numerous other activities such as traffic control to expedite evacuation, provision of transportation assistance for evacuees, shelter and care of evacuees, and provision of security for

evacuated areas. In some conditions, even floodfighting activities may be an important part of the overall effort to improve safety.

Activities included in preparedness plans for damage reduction often overlap those included for safety purposes. For example, dispersal of public equipment to assure continued provision of vital services may also remove equipment from the area of expected flooding and thereby reduce the damage potential. Special utility management for safety purposes may also reduce damage done both to and by gas, electrical and other systems. Similarly, traffic control and floodfighting may be important to damage reduction efforts.

Other activities may be undertaken solely for the purpose of damage reduction such as temporary relocation of property and contingency floodproofing. Still others may be undertaken for damage reduction but also serve to reduce flood related costs and inconveniences apart from those caused by direct damages. For example, proper management of a water supply system during flooding may reduce the extent of decontamination required and hence the need to boil or import water in the post-flood period. Likewise, temporary relocation of property may reduce the post-flood costs for collection and disposal of debris. Temporary protection of sewage pump stations or sewage treatment plants may make the difference between immediate reestablishment of service after the flood or months of either releasing raw sewage or operating at a reduced level of service. Actions taken to ensure prompt restoration of sewage treatment plants are early shutdown and removal of pumps, use of high flow bypasses during floods or preparation of an emergency plan.

Emergency plans must be detailed if their full value is to be realized. Specific assignments of responsibility must be made for each task.

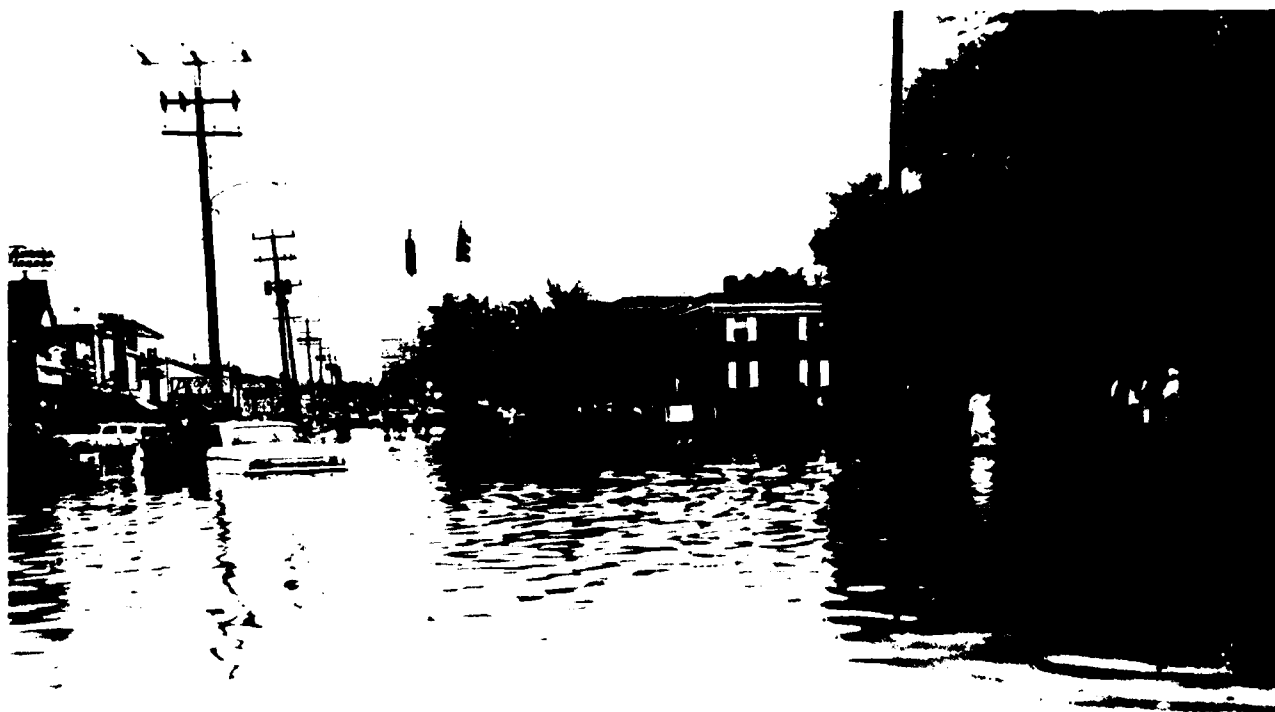
Activities can also be included in plans specifically to reduce costs other than through the prevention of direct damages. Such measures focus on the post-flood period and include things like provisions for distributing information on salvaging flood-damaged property, prevention of losses due to various secondary problems, and early restoration of normality. Preparedness plans can also include information on disaster aid programs and provide for collection of information on which federal and state disaster declarations are based.

### Applicability

The design of flood warning systems offers many opportunities for trade-offs between cost, accuracy, speed of operation and other aspects.

Systems may be designed to suit all or almost all flood situations. The principal determinant in system design is the available warning time. Even for cases of flash flooding, sufficient warning time can often be provided to reduce the risk to life. Opportunities for property protection increase with longer warning times. Preparedness plans must be coordinated with warning arrangements to ensure that planned actions can be accomplished in the time available.

Warning systems are only useful where some risk to life or property exists. Their applicability is therefore limited in the case of undeveloped lands. However, the assessment of applicability should recognize the need for warning in *undeveloped but populated areas*, such as recreational sites.



*Floods sometimes occur quickly. A flood warning system can provide the few minutes of warning necessary to evacuate people and vehicles. This photograph was taken near Alexandria, Virginia.*

Preparedness plans can be devised to benefit almost any area. Even very short warning times do not limit the need for or applicability of preparedness planning. For instance, simply throwing a switch to shut off electricity requires little time but may make a significant difference in losses to motors and other electrical equipment. Driving or hauling vehicles to higher ground is another simple but significant measure. Benefits can usually be obtained from preparedness planning regardless of the type of development located in the flood hazard area.

## **Economic Considerations**

The major costs for flood warning systems depend primarily on the type of flood recognition and warning dissemination systems employed. Simplified systems based on collection of data by volunteers and manual analysis of the data using charts and tables are relatively inexpensive. Initial costs are often in the range of \$100 to \$1,000 for installation of the necessary gages and continuing costs are very small. At the opposite end of the spectrum, highly sophisticated systems featuring computer monitoring of automatic gages and computerized analysis of data may cost over \$100,000 to implement and another \$1,000 to \$10,000 annually for operation and maintenance.

Many communities are able to provide for warning dissemination at virtually no cost by using available emergency warning systems, sirens on police and fire vehicles and commercial radio. The cost of a siren or other type of mass warning system depends on the size of the area to be served and provisions necessary to assure its reliability such as use of radio triggering and independent power supplies.

Minimal preparedness plans primarily consist of organizational arrangements involving no cost. As plans become more comprehensive, costs are often encountered for stockpiling

of emergency equipment and supplies, modification of structures and facilities to enable better performance of preparedness actions, and training of staff. The costs must be evaluated on a case-by-case basis.

## **Major Public Works**

The objective of major public works is to impound, divert or otherwise control flood waters to keep them away from developed and/or populated areas.

## **Description**

Major public works include dams and reservoirs, levees and floodwalls, channel alterations, and diversions.

Dams and reservoirs capture and detain floodwaters upstream of flood-prone areas for subsequent gradual release. Sites capable of storing sufficient amounts of water are required upstream but fairly close to the area to be protected. In addition, the site must usually be "available" in the sense that it does not contain significant urban development or any archeological or historical sites deserving preservation.

A positive feature of reservoirs is their potential for reducing flooding in several downstream communities. Some other flood-modifying measures only provide flood relief in their immediate vicinity. Another favorable aspect of reservoirs is their potential for providing additional benefits related to recreation, hydroelectric power generation, water supply and other purposes.

Protection afforded by dams is greatest in the immediately downstream area. Protection further downstream is reduced by tributary flows and runoff entering the stream. Protection also decreases over time as the reservoir fills with sediment.



*Dams and reservoirs can sometimes reduce flood problems and, at the same time, provide recreation, hydroelectric power and other benefits. This is Norris Reservoir.*

A major disadvantage of dams and reservoirs is that downstream residents may not realize that these structures are only designed to provide protection up to a particular size flood. A false sense of security is likely to develop and induce further floodplain development and encroachment in downstream areas unless complementary land use controls are implemented. Dams and reservoirs can also have adverse social and environmental impacts and require significant amounts of maintenance. Though the possibility is extremely small, some potential always exists that a dam will fail, causing great damage and or loss of life.

Dams can also play a role in the management of coastal floodplains. Constructed across the lower end of streams, they can prevent storm surges from travelling up the stream valley and flooding inland areas. However, this use is uncommon.

Levees and floodwalls are built to contain floodwaters within the stream and a selected portion of the floodplain. Seawalls serve much the same purpose in stopping ocean or lake waves. Each of these measures protects only the area immediately behind it and only against the selected design flood.



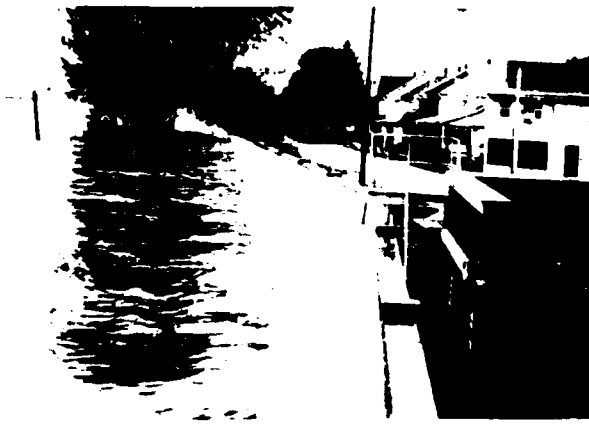
*This levee near Forty-Fort, Pennsylvania, has an opening for the rail line. The slots in the walls hold logs which are stored nearby for use during floods.*

One of the major advantages of levees, floodwalls and seawalls is the flexibility to protect a specific site as well as a regional area. Unlike dams and reservoirs, levees and floodwalls may be used to protect a single community or a portion of a community. However, as with dams and reservoirs, a false sense of security may develop concerning the degree of protection provided. Floods exceeding the level for which levees and floodwalls are designed can cause disastrous losses of life and property.

Unless designed as part of a comprehensive program, levees and floodwalls also have the potential to

increase flooding in other areas. Blocking off a flood's natural course on one side of a stream normally results in more widespread flooding on the other. Containing the flood in a reduced flood channel by levees or floodwalls on both sides of a stream can create a bottleneck which raises flood levels and increases flooding in upstream and downstream areas as well as increasing velocities immediately downstream. Seawalls are highly susceptible to erosion. They may also have the effect of increasing erosion in adjacent areas.

Levees and floodwalls also often have other undesirable environmental



*Floodwalls of reinforced concrete take little space and can be suitable for use in heavily developed areas. This wall prevented flooding in Sunbury, Pennsylvania, when Tropical Storm Agnes struck in 1972.*

impacts including destruction of wildlife habitat and blocking access to and views of the stream or ocean. For communities straddling rivers, high levees or floodwalls may significantly impede travel between sections of the community.

Levees, floodwalls and seawalls can also interfere with the natural drainage from the protected area to the stream or ocean. To prevent flooding of low lying areas behind the protective works, the structures must usually be supplemented with a pumping system or include other provisions for disposal of internal drainage.

Levees and floodwalls are not as adaptable to multiple use as reservoirs. However, features can sometimes be incorporated to provide access to riverfront or beach areas, fishing sites, boat launching lanes and bike-ways. Lands acquired for levees and floodwalls may also provide trails and even road rights-of-way for recreational purposes.

Channel alterations reduce flooding by increasing the flow carrying capacity of a stream. Common types of alterations include: straightening, deepening and widening; removal of debris; paving of the channel; raising or enlargement of bridges and culverts which restrict flow; and removing unused dams which interfere with flow. Small streams can also be supplemented with underground conduits.

Channel alterations reduce the height of a flood. It is sometimes possible with extensive reconstruction of a stream to contain major floods within its banks. Unfortunately, channel alterations may also accelerate flows enough to exacerbate downstream damages.

Channel alterations are like levees and floodwalls in that protection can be afforded to either a specific site or a regional area. But channel alterations have the added advantage of not being subject to sudden or disastrous failure. In addition, alterations can sometimes be designed to serve navigation, recreation and other purposes by the addition of features such as boat launching facilities.

The environmental impact of a channel alteration depends on the specific techniques which are used. Some, like reconstruction of bridges and culverts, usually have only a temporary impact during construction. Widening, deepening or paving of channels may effectively destroy fish and wildlife habitat and other of the stream's natural values for several years, decades or perhaps permanently.



Diversions intercept flood flows upstream of the area to be protected and convey them in an artificial channel to a point of safe disposal. Diversions may completely reroute a stream or only collect and transport flows which exceed the safe channel capacity.

A favorable feature of diversions, shared with reservoirs, is the potential for protecting several communities with one major facility. A negative aspect, also shared with reservoirs, is the false sense of security which may develop in the protected areas. Diversions of stream-flow may also conflict in some areas with state laws regarding transfer of water between basins or watersheds.

## Applicability

Dams and reservoirs are used most frequently on small and moderate sized streams. The large areas of land required to store the flood flows of major rivers are usually not available. Because of cost, large dams and reservoirs are usually only feasible where they protect urban areas or high value agricultural lands. For some heavily developed urban areas, dams and reservoirs may provide the only practical means of significantly reducing flood damages for large groups of properties.

Levees are normally constructed of earth with a base width several times greater than the levee's height for stability. As a result, levees of



*The channel on the right diverts high flows around the developed area.*

more than a few feet in height require significant space be available between the stream and the property to be protected. Levees are best suited for use along large rivers where construction is less likely to be a severe encroachment on the floodplain. Floodwalls and seawalls are usually constructed of concrete and/or steel and require less space. This allows their use in congested areas.

Channel deepening is not suited to major streams because sediments can fill in the excavated area and quickly undo the improvement. Frequent redredging may be necessary to maintain a deepened channel even on smaller streams. This can become a significant cost to local governments. Care must also be taken to avoid causing increased erosion.

Diversions are particularly well suited for protection of intensively developed areas because no acquisition of land or construction is required within the protected area. However, opportunities for diversions are often limited by topographic and subsurface conditions and the requirement for a receiving channel of adequate capacity.

## **Economic Considerations**

Major public works involve large amounts of construction and high capital costs. Most of the measures also require significant amounts of operation and maintenance on a regular basis for successful and safe use. In addition, the several measures also

have some common disadvantages including:

- Lengthy and complex planning and design.
- Potential for contributing to worsening flood damages outside the project area.
- Potential for major losses should design levels be exceeded.
- Possible detrimental effects on the natural environment.

The cost of major public works projects depends on their size, site-specific factors such as geologic and soil conditions, and design provisions which serve purposes other than flood control. Major items of cost are those for:

- Detailed planning and design.
- Acquisition of necessary lands.
- Construction.
- Actions required to identify and mitigate environmental impacts.
- Operation and maintenance.

Measures which control floods have the significant advantage of enabling full economic development of a community. A second consideration is that such measures usually require little disruption to homes, businesses and lifestyles of the kinds required by some of the site-specific measures described in Chapter 3.

# Chapter 5

## DEVELOPING A COOPERATIVE COMMUNITY FLOOD LOSS REDUCTION PROGRAM

Success in reducing flood losses depends on selecting and using appropriate measures. This requires a sound understanding of the flood problem and the area at risk and careful analysis of alternatives.

The variety of flood loss reduction techniques described in Chapters 3 and 4 assures that a plan providing some reduction of losses can be developed for almost any area. However, measures differ significantly in the manner of contributing to flood loss reduction, cost, operational requirements, and other aspects.

### Caution

The measures used must be chosen with great care since use inappropriate for the circumstances may be unnecessarily expensive. Even worse, measures used improperly may not provide the expected type and extent of loss reduction or could result in greater damage than if no action were taken at all.

The major steps in selecting flood loss reduction measures are:

- Analysis of the flood hazard.
- Analysis of the area at risk.
- Preliminary screening of measures to eliminate those not appropriate for use.
- Evaluation of remaining measures and/or combinations of remaining measures.

### **Analysis of the Flood Hazard**

Flood loss reduction measures differ in the types of flood situations for which they are suited. For example, floodproofing by closure of openings is only useful against relatively shallow flooding. Applicability of some measures may also depend on the expected frequency of flooding with more expensive measures being economically unjustified to protect against rare incidents of damage. In addition, the choice of measures is affected by the size and location of the area subject to inundation, speed of onset of flooding and numerous other flood characteristics. In analyzing the flood hazard, factors which help to determine the suitability of each measure must be identified.

### **Information Needed**

Situations across the Nation are too variable to list all information necessary for planning in a particular case. However, useful information in most cases is that relating to:

- Identification of potential sources of flooding including overflow of intermittent and perennial streams, high waves and storm surges, and high groundwater levels.
- Identification of potential causes of flooding from each source including intense or prolonged rainfall, snow-

melt, ice and debris jams, high winds, and combinations of these and other causes (such as dam failures).

- Characteristics of the flooding which could result from each source and cause of flooding (or combination of sources and causes) including season of occurrence, area inundated, depth of inundation, water velocity, expected frequencies of different flood stages, sediment and debris content, speed of onset, and duration.

## Sources of Information

Information on the sources, causes and characteristics of flooding is often available through the governmental agencies identified in Appendix B, Sources of Assistance.

Sometimes, federal agencies will assist in collection of flood hazard data including the study of flood problems. However, such assistance is subject to various restrictions including availability of agency funds and staff. Opportunities and conditions for obtaining assistance should be discussed individually with each agency.

A search of back issues of newspapers is often helpful in determining the flood history of an area. The general time periods to be researched can usually be identified from information available from state and Federal agencies.

There is no one place to begin the information collection process which is best in every part of the country. Simultaneous letters to all appropriate agencies requesting information on useful data they may have available is a start.

## Analysis of the Area at Risk

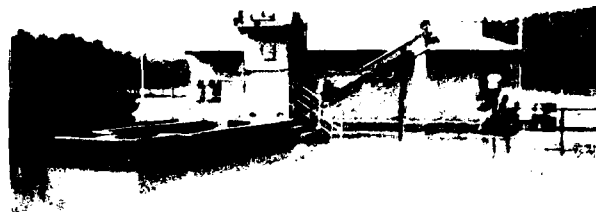
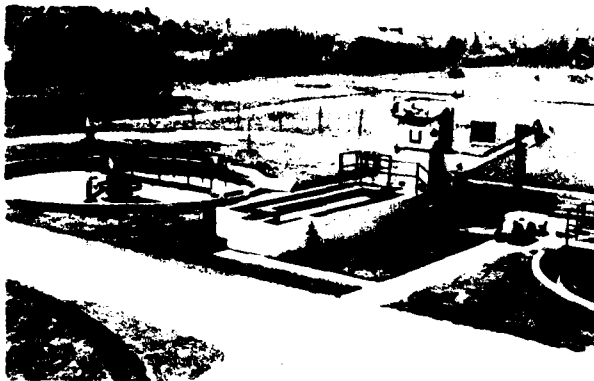
The extent of development in the area at risk has considerable influence on the selection and use of flood loss reduction measures. For example, measures providing areawide protection are more likely to be economically

justified for use in heavily developed areas than in areas with only scattered developments. The type of development in the area at risk is also important. Some measures suitable for use with one type of property are not practical for use with others. For example, efforts to make a structure watertight are not generally applicable to wooden structures. Even the type of potential flood losses has a bearing on the selection and use of measures since some measures protect contents, some protect both structures and contents, and some emphasize health and safety. Information on the area at risk is necessary in order to select the appropriate measures for use.

## Information Needed

Information about the area at risk generally needed in selecting appropriate measures for use is that concerning:

- Overall characteristics of the area including size, and existing and planned land use.
- Nature and extent of existing developments to be protected including type of use (e.g., residential, commercial, etc.), style and material of construction (e.g., two story brick building with basement), and condition of structures.
- Location of facilities or structures in the area which warrant special attention (e.g., buildings housing police, fire, medical or other vital services; buildings for storage of toxic or other dangerous materials; buildings with potential for exceptionally high losses).
- Characteristics of the area which limit or prevent use of a particular measure such as space between structures or between structures and stream channels, foundation conditions, or availability of alternative sites for relocation.
- Nature and magnitude of past and potential flood problems including



*Floods often disrupt vital community facilities such as this sewage treatment plant. Months may be required to return to normal operations. Gas, electrical, fire, law enforcement and other community services may also be interrupted.*

distribution of losses between properties, structures and contents, relationships between flood depths and damages, flood frequencies and problems relating to health and safety.

- Warning systems, preparedness plans and other measures already in place to reduce flood losses or mitigate their impact.

Other characteristics may also be important in determining the appropriateness of measures for use. A careful analysis of the area at risk is required to avoid overlooking any important factors. Characteristics of the area at risk may vary from one part of the area to another, requiring a separate analysis for each.

## **Sources of Information**

General information concerning the area at risk is often available from U.S. Geological Survey topographic maps and assessor's maps. In addition, local planning agencies sometimes have reports and studies available relating to housing, transportation, zoning and other purposes which describe the area and the nature of past flood problems. Information is also often available from maps and studies prepared for the National Flood Insurance Program. However, it is necessary to investigate the area to obtain the full complement

of needed information. Investigations may range from simply driving through the area to conducting detailed inventories and studies.

## **Preliminary Screening of Measures**

Preliminary screening of measures helps to determine which measures are unsuitable and avoids spending effort on their detailed analysis. The basis for this screening is the information collected concerning the flood hazard and the area at risk.

A portion of the screening may be done for the area as a whole or for various subareas. For example, closure of openings may be ruled out in areas where all structures are subject to flood depths above the practical upper limit of that technique. Similarly, a levee might be dropped from further consideration because of space restrictions or foundation conditions.

Following this type of broad brush analysis, measures can be considered on a property by property basis, eliminating from consideration any measures incompatible with the characteristics of individual developments or which would not provide the type of protection required. The impact on businesses of relocation and the impracticality of raising large structures are examples of the types of

incompatibilities to be identified in this phase of the screening process.

All of the measures not eliminated in the preliminary screening presumably have some degree of applicability. More detailed evaluation is then required to determine the relative merits of each.

## Evaluation of Measures

The evaluation of measures remaining for consideration involves four steps:

- Formulation of alternative plans.
- Analysis of each alternative plan.
- Comparison of the alternative plans.
- Plan selection.

## Formulation of Alternatives

Alternative plans may differ in a variety of ways. For instance, plans may differ in the measures included, with some making use of only a single measure while others combine two or more measures. Most plans for flood loss reduction include more than one measure since land use regulation and flood warning and preparedness complement most other measures and add to the overall reduction of losses. Alternatives may also be developed which combine use of the same measures but differ in the priority and emphasis put on each. One alternative may, for example, use closure of openings wherever possible and supplement this where needed with raising and relocation while another reverses this approach. Still other alternatives may be formulated which differ in assignment of the responsibility for implementation and operation. Plans may consist entirely of community-wide measures, site specific measures or various combinations of the two. Plans combining measures must deal with coordination between all of the affected parties.



*Hearings such as this one at Allen-ville, Arizona, are an important means of informing the public about flood problems, collecting information needed for planning, and deciding on a solution.*

## Analysis of Alternatives

The analysis of alternatives provides the information necessary to compare the respective merits of each. The most important comparisons to be made concern:

- Economic benefits and costs.
- Financial requirements.
- Practicality and effectiveness.
- Political acceptability.
- Environmental and social aspects.

The major benefits considered in analysis of a flood loss reduction plan are those related to:

- Damages to activities which would continue to use the floodplain if the plan were not implemented.
- Business losses.
- Emergency costs.

- Costs for items such as flood insurance which are associated with occupancy of the land.
- Market value of land in the area.
- Availability of land for new uses.
- Enabling more intensive use of properties by existing activities.

The value of benefits related to these and other effects of a plan are determined by examining the future situation with and without the plan. Since flood losses vary, determining values such as reductions in business losses requires relating the value of loss to various flood heights. Next it is necessary to assign to each flood height an expected annual frequency (i.e., a 1%, 5% or other chance of occurring any year). Flood frequency information often can be obtained from federal agencies listed in Appendix B. Losses can then be computed as an average annual value for comparison on an equivalent basis with costs by multiplying losses at selected flood heights by expected frequencies and summing the products.

The costs to be considered include the plan's initial implementation costs and continuing costs for operation and maintenance of its flood loss reduction measures. Detailed analysis is often necessary to accurately identify all of the costs associated with a particular plan. As in the case of benefits, costs are put on a common basis by computing an average annual value. Periods of 50 to 100 years are usually used by public agencies for amortizing initial costs.

The financial requirements of a project concern the outlay of funds required for its design, implementation, operation and maintenance. Matters of particular concern in this analysis are the overall total cost; the distribution of cost among parties participating in implementation, operation and maintenance; the time at which costs must be met; and the means by which costs can be met (i.e., cash, services or other).

Practicality and effectiveness relate primarily to:

- Reliability and extent of protection;
- Availability of the legal, technical and other capabilities required to carry out the plan.
- Capability to modify the plan.

Reliability refers to the dependability of the measures included in the plan to perform or be performed properly under all foreseeable conditions. Plans which depend on highly complex arrangements or equipment may be unreliable. In some cases, failure of a plan to provide expected protection may increase losses beyond those which would have occurred in its absence.

The extent of protection provided by a plan can vary in several ways. For example, a plan may provide protection against only some of the sources and causes of flooding. Another plan may provide protection only up to a certain level of flooding. Still another plan may provide only a partial reduction of losses. The common measurement of protection is the average annual loss to be expected if the plan is in operation. As in the case of estimating benefits and costs, the value of this residual loss is based on the estimates of losses with and without the plan.

Each plan requires some set of legal authorities and technical capabilities for implementation, operation and maintenance. These may vary from the authority to regulate land use to the technical competence to operate a computerized flood forecasting system. Plans which require authorities and capabilities not immediately available from any of the participants require close scrutiny.

Plans which depend on governmental action must also be acceptable from a political standpoint if they are to be implemented successfully. This type of analysis is separate from the other types of analyses which are more oriented to technical concerns.

Political acceptability relates to such things as equitability in the distribution of benefits and costs, compatibility with or promotion of other community goals, and accordance with the community's traditional modes of operation such as distribution of responsibility for various types of actions.

Environmental and social aspects of alternative plans may vary considerably and usually require specific attention, particularly where large scale public projects are concerned. Investigations of environmental impacts need to consider both short-and long-term impacts associated with construction, changes in land use, and commitments of resources required by the plan. Flood loss reduction projects involving extensive construction often have significant adverse impacts on water quality, wildlife habitat and other environmental values. Social impacts arise from such things as

relocation of people and activities, increased traffic and effects on community growth. In some cases, the impacts may be substantial.

## **Comparison of Alternative Plans**

Some of the findings from the analysis of alternative plans can be compared directly. Estimated costs and benefits, for example, are usually compared in the form of a ratio of benefits to costs which indicates the economic efficiency of the plan. Less commonly, projects are compared on the basis of their net benefit or a ratio of net benefits to cost. Financial information developed during analysis is also directly comparable since it involves a discrete set of numbers.

Comparison of other findings which result from the analysis of alternatives is more subjective. For



*Planning sessions should involve all of the participating governments and agencies as well as representatives of the public. All viewpoints need to be considered in selecting the best overall plan.*



example, a plan including a channel improvement may result in destruction of a valuable fishery while another based on a levee may take up valuable parkland. Similar choices may exist with respect to the level of protection to be provided, reliability of the plan and other factors. These must be decided largely on the basis of the participants' judgement.

## **Plan Selection**

Selection of the best alternative plan must consider all of the objective and subjective information developed during the investigation and evaluation of alternatives. The selection process involving government action usually includes public hearings or other means of obtaining public input.

# Chapter 6

## COOPERATIVE COMMUNITY ACTIONS CAN REDUCE FLOOD LOSSES: A CASE STUDY

Flood losses have been reduced significantly through the cooperative efforts of communities and industry. The case study describes one such program that has produced multi-million dollar savings.

Many cooperative actions can be undertaken by communities and industries to reduce flood losses. This chapter describes the county-wide flood warning system developed in Lycoming County, Pennsylvania, and the flood preparedness arrangements made by the Sprout-Waldron Division of Koppers Company, Inc., a large industry in the County. It points out the significant benefits which can result from cooperation between local government and industry managers.

Recent floods have proven the County's flood warning program and Sprout-Waldron's flood preparedness arrangements to be outstandingly effective. Both the flood warning system and the industrial flood preparedness arrangements may be easily used by others as a source of ideas and a guide for action. Lycoming County and the Sprout-Waldron facility are typical in several respects of many places across the Nation, giving the example wide applicability. These examples show how local initiative and cooperation can reduce flood losses.

Concluding the chapter are a series of observations on points, drawn from the case study, that are relevant to the flood loss reduction efforts of other communities and industry.

### Description of Case Study Area

Lycoming County is located in north central Pennsylvania, about 80 miles north of Harrisburg (Figure 4).

Ninety-eight percent of the County lies within the drainage basin of the West Branch Susquehanna River. Sprout-Waldron's main plants are located at Muncy, Pennsylvania, a small community situated in the southeastern portion of Lycoming County. Figure 5 shows the principal features of the area.

The County marks the physiographic transition from the Appalachian Vallemont to the Allegheny High Plateaus, with this division clearly marked by the West Branch Susquehanna River. Excepting several mountainous ranges in the northern part of the County which reach an elevation of 2,200 feet and major stream valleys, the County has an average elevation of about 1,000 feet above sea level. Slopes in the area are relatively steep and stream gradients range from as much as 10 percent in the uplands to about 5 percent in the lower valleys.

The dominant waterway in Lycoming County is the West Branch Susquehanna River which flows for 38 miles from the western to southern borders of the County. The river's major tributaries within the County are Pine Creek and its tributary Little Pine Creek, Larrys Creek, Lycoming Creek, Loyalsock Creek, and Muncy Creek. There are also numerous minor tributaries which flow directly to the West Branch Susquehanna River. Altogether, the County has about 2,200 miles of streams. Table 3 lists the drainage area and length of the West Branch Susquehanna River and its major tributaries.

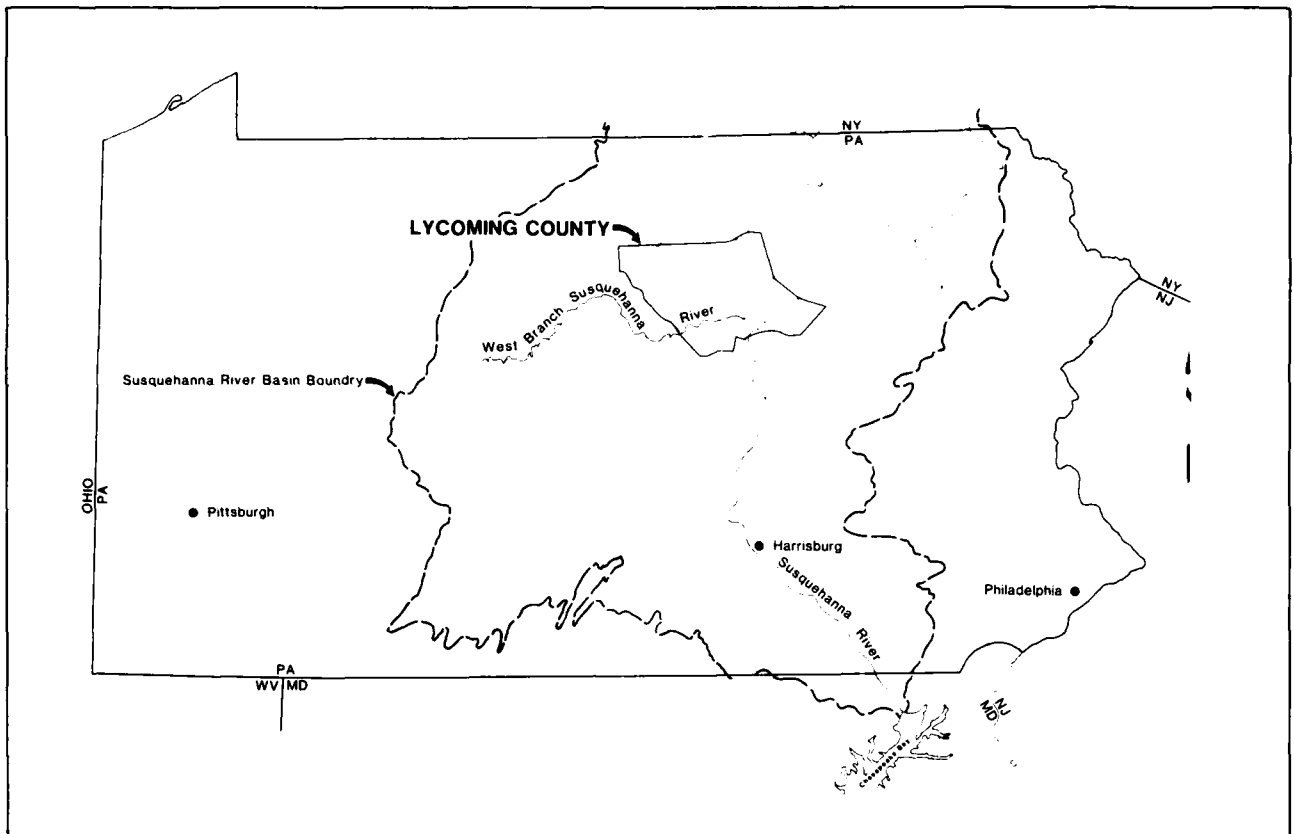


FIGURE 4. LOCATION OF LYCOMING COUNTY, PENNSYLVANIA.

The normal weather pattern in Lycoming County is a succession of eastward moving high and low pressure systems. This produces weather changes every few days in winter and spring and somewhat less frequently in summer and fall. Low pressure systems often bring either rain or snow. Moderate to heavy precipitation results from storms which periodically develop along the Southeastern coast of the United States and move northward. Hurricanes or tropical disturbances occasionally take a path through the area and produce heavy rainfall. These storms drop as much as 4-8 inches of rain on the County in a 24 hour period.

Average precipitation ranges from about 37 inches in the northeastern part of the County to about 40 inches at its southeastern boundary. The heaviest rainfall usually occurs during May and July. There are normally about

35 thunderstorms per year which account for most of the summer rainfall.

Approximately 50% of annual rainfall is returned to the atmosphere through evapotranspiration, 35% infiltrates the ground and 15% becomes direct runoff. The runoff from most tributary areas is rapid due to their steep slopes and relatively compact shape. Stream flows fluctuate widely on a daily and monthly basis.

Approximately 75 percent of the County's 1,215 square mile land area is undeveloped due to State ownership and remoteness and remains heavily forested. Another 20 percent, generally the flatter areas in the river valleys and the milder slopes, are in agricultural uses. Urbanized lands make up only about 5 percent of the County, a large portion of which is on the lower lying floodplains.

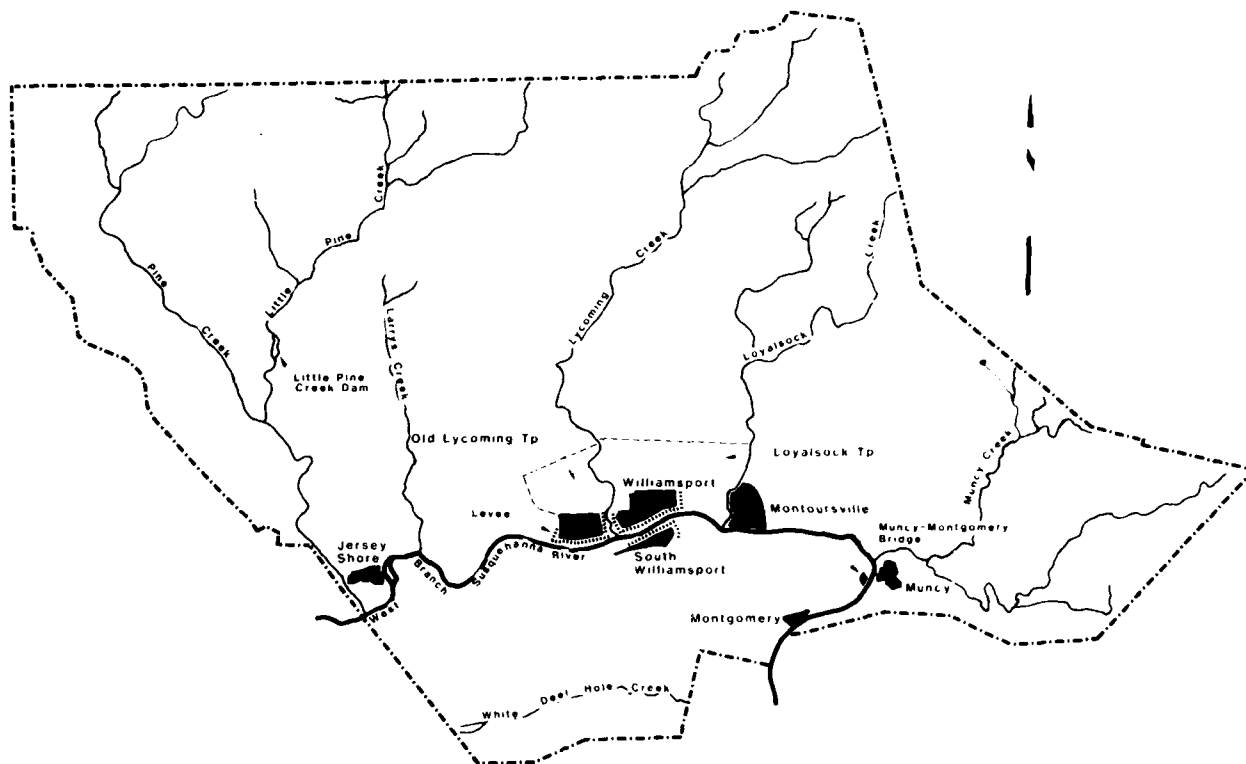


FIGURE 5. PRINCIPAL FEATURES OF LYCOMING COUNTY, PENNSYLVANIA.

The County's estimated 1980 population is 118,550. It is expected to increase to 122,600 by the year 2000. The major city in the County is Williamsport with an estimated 1980 population of 33,454. Other sizable communities in the County and their estimated 1980 populations are South Williamsport (6,584), Montoursville (5,403), Old Lycoming Township (5,229), Jersey Shore (4,642), and Muncy (2,700). The estimated 1980 population of the greater Williamsport metropolitan area is approximately 70,000. The majority of the County's population is concentrated along the West Branch Susquehanna River.

Lycoming County ranks second in Pennsylvania in terms of cultivated acres. Agricultural operations are presently intensifying and shifting to higher value crops. However, the area devoted to agriculture is gradually decreasing, primarily due to the expansion of urban and suburban areas and

increasing demand for recreational lands. Commercial and industrial activities are simultaneously becoming a more important part of the overall economic base of the area. Employment in the County is diversified with 10 of the 20 Standard Industrial Classification (SIC) job categories represented. Eight major SIC groups reported employment exceeding 1,000, with no single group providing as much as 15 percent of the total employment; consequently, no single industry dominates the County economy. The Sprout-Waldron Company is one of the County's larger employers.

## Flood Problems

Flooding is an annual event along most of the streams in Lycoming County. Lycoming Creek, for example, flooded 44 times in the period from 1914 to 1958. Recent major flooding in the County occurred in 1950, 1959, 1964, 1972, 1975 and 1979. When floods do occur,

TABLE 3  
CHARACTERISTICS OF MAJOR STREAMS  
LYCOMING COUNTY, PENNSYLVANIA

<u>Stream</u>	<u>Drainage Area (sq. mi.)</u>		<u>Length (mi.)</u>
	Total	In County	In County
West Branch Susquehanna River at Williamsport	5,682	813	23
Pine Creek	983	327	72
Little Pine Creek	185	166	16
Lycoming Creek	498	272	35
Loyalsock Creek	514	162	60
Larrys Creek	87	87	20
Muncy Creek	455	136	33

the waters run fast and hard in the upper tributaries because of the mountainous terrain. Floods from the West Branch Susquehanna River are slow rising but deep and laden with mud. Flooding causes damages to roads, bridges and other public property as well as to railroads, crops, residences, commercial and industrial structures, and contents of structures. The repetitive losses are large enough to strain the regional economy and hinder the financial capability of local governments to carry out other programs. Floods also pose a severe hazard to life, both for those who may be caught in them and those who must undertake rescue efforts.

The most severe flood of record occurred in June 1972 due to rains from Tropical Storm Agnes. The flooding lasted from 3:00 p.m. on June 22, to 7:00 p.m. on June 27. The level of the West Branch Susquehanna River rose at a rate of more than 1 foot per hour at times during this period and finally reached a level of 35.75 feet at Williamsport. This level was 32 feet

higher than normal for June and almost 16 feet higher than flood stage. The levee system at Williamsport contained the flow but serious problems of internal drainage occurred. At Muncy, Pennsylvania, the water level reached 37.45 feet, 14.5 feet above flood damage stage. More than 34,000 acres of Lycoming County were under water. The flooding was severe along all of the streams in the County and caused extensive damage to unprotected areas. About 13,000 buildings suffered some kind of damage. Of those, 2,800 homes were either extensively damaged or destroyed. In addition, 350 mobile homes were flooded, totally destroying about 150 of them. Total damage in the County was nearly \$54 million.

Another major flood occurred in September, 1975, as a result of heavy rainfall caused by Tropical Storm Eloise south of the area. Eloise did not penetrate as far inland as had Tropical Storm Agnes in 1972, thus western parts of the County were spared major losses. However, flood levels along streams in the eastern portion

were within a few feet of that which had occurred in 1972. Muncy Creek was particularly hard hit. Damages and other losses in the County due to the 1975 flooding was in the multi-millions of dollars.

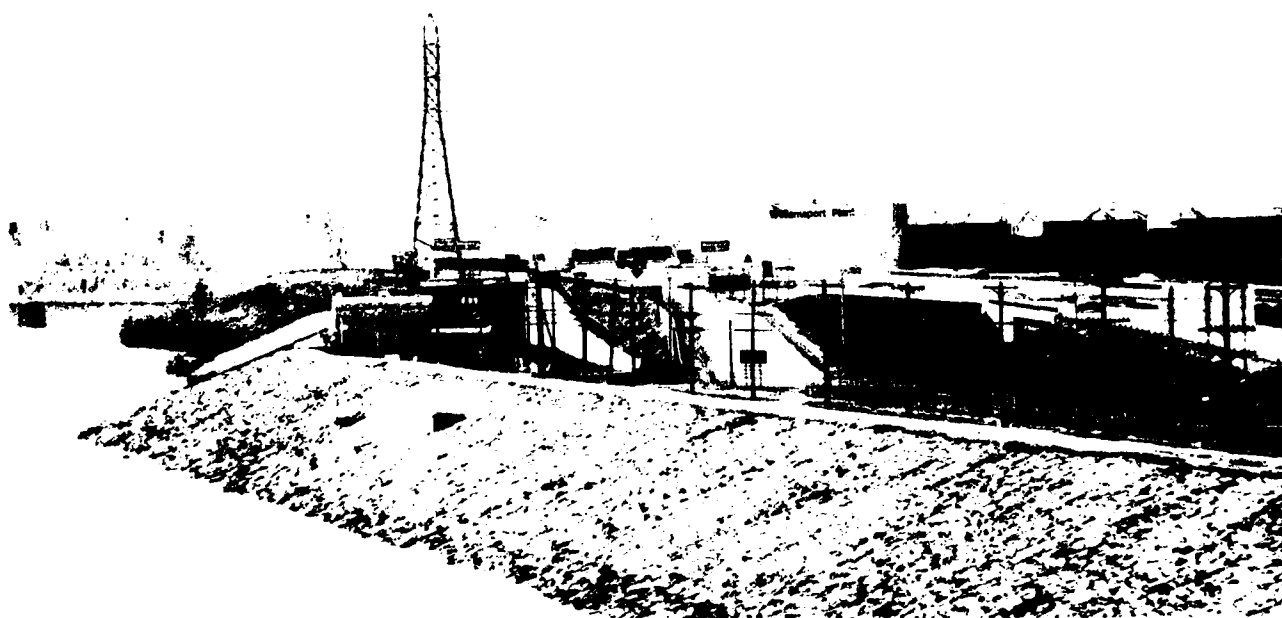
Severe flooding which rivaled that following Tropical Storm Eloise also occurred in various County watersheds in March of 1979.

## General Adjustments

Municipal and County governments have pursued an aggressive program of floodplain management for several years. Numerous programs have been or are being carried out to reduce flood losses. The following are some of the more important efforts.

## Williamsport Local Protection Project

Williamsport and South Williamsport are protected from flooding by 3,520 feet of levee and 4,125 feet of floodwall, located on both banks of the West Branch Susquehanna River and on both banks of Lycoming Creek. The project provides protection against discharges equal to those of the flood of March 1936. Eleven pumping stations are included in the project to drain the area behind the levee and wall. The project was constructed in the early 1950's by the Baltimore District Corps of Engineers and is operated by local governments. A study of the feasibility of raising the levee to provide a higher level of protection was initiated in 1980 by the Corps of Engineers.



*Levee Unit 3, Williamsport Local Flood Protection Project. The small building at left center houses pumps which remove runoff that collects behind the levee.*

## **Storm Water Management**

Staff of the Lycoming County Planning Commission are aggressively developing procedures for implementing the Pennsylvania Stormwater Management Act. The County is implementing a planning process drawing upon the cooperative efforts of federal, state, and local governments to prepare the county stormwater management plan called for by the Act.

## **Beltway-Dike Project**

The Baltimore District Corps of Engineers is adding an impervious core to U.S. 220 beltway under construction to form a levee. The levee and a pumping station will provide protection to a commercial section of Loyalsock Township subject to flooding by the West Branch Susquehanna River.

## **Little Pine Creek Dam**

The Pennsylvania Department of Environmental Resources constructed, operates and maintains Little Pine Creek Dam, located on Little Pine Creek. The dam and reservoir provides sufficient flood control storage to contain about 2.5 inches of runoff from the upstream drainage area. The available storage reduces peak flows along Little Pine Creek but has only a minor effect on flooding along the West Branch Susquehanna River. The effectiveness of the dam and reservoir is being reduced over time by siltation.

## **Flood Insurance**

Fifty-one of the 52 municipalities in the County are enrolled in the National Flood Insurance Program (NFIP). The Lycoming County Planning Commission visited each municipality in the County to explain the program and assist in enrollment and in the development of land use ordinances. The Lycoming County Land Development and Subdivision Ordinance was adjusted to meet requirements of the NFIP. The County administers subdivision reviews

for 23 flood-prone communities. Further revision of the County subdivision ordinance is underway to bring it into compliance with the Pennsylvania Flood Plain Management Act. As of November, 1980, there were 5,250 flood insurance policies in effect in the County with a combined coverage of \$92,490,100 on buildings and \$44,190,300 on contents.

## **Channel Alterations**

No recent channel alteration projects have been undertaken in the County although evidence of past projects can be found in some areas. However, in the past, stream channels have been unsatisfactorily altered by removal of debris and other obstructions following disaster declarations. To reduce the adverse effects of past alterations, such as loss of habitat, gravel deposition on streambanks, and faster runoff, the County Conservation District has formed a team to plan and inspect such projects. Team members are drawn from the Planning Commission, the County Conservation District, U.S. Soil Conservation Service, Pennsylvania Department of Environmental Resources, Pennsylvania Fish Commission, and others knowledgeable about planning and the County's waterways. The team approach worked successfully in the period following Tropical Storm Eloise and is now being implemented in other counties in the SEDA-COG region.

## **Flood Warning**

The County operates a flood warning system in conjunction with the National Weather Service and Sprout-Waldron. This system is described in detail in the latter part of the chapter.

## **Relocation**

Many residences and businesses subject to repeated flooding were moved as part of federal-state disaster urban renewal projects administered by the Lycoming County Redevelopment Authority. The project locations and planned

uses of project areas are listed in Table 4. The implementation of two other proposed relocation projects were not approved by municipal planning commissions.

## Preparedness Planning

The Lycoming County Emergency Management Agency has developed a basic plan for all emergency operations. The plan applies to each of the 52 municipalities in the County.

## Further Studies

A variety of further adjustments to reduce flood losses and/or to improve the performance of the existing flood warning and preparedness measures are being considered. These include:

- An investigation by the Soil Conservation Service, U.S. Department of Agriculture, of the potential application of nonstructural measures in the Muncy Creek Watershed.

- An investigation by the Lycoming County Emergency Management Agency into the use of cable television to disseminate flood warnings.

## Sprout-Waldron Flood Preparedness Program

As noted at the beginning of the chapter, the Sprout-Waldron Division of Koppers Company has developed extensive flood preparedness arrangements.

Sprout-Waldron manufactures non-electrical processing equipment for the paper, pulp, fiberboard, feed and grain, chemical, and pure food industries. It's headquarters and major manufacturing facilities are located in the Borough of Muncy, Pennsylvania. Included in the Muncy operations are a modern foundry, machine shop with numerically controlled equipment, fabricating shop capable of making exceptionally large fabrications, complete metallurgical laboratory, heat treatment operation, and lesser produc-

TABLE 4  
FLOODPLAIN RELOCATION PROJECTS IN LYCOMING COUNTY\*

Project Location	Units Relocated		Structures Demolished	Reuse of Project Area
	Residential	Business		
Duboistown	26	3	19	Residential
Jersey Shore	152	28	93	Res./Bus.
Montgomery	18	3	23	Park
Montoursville	20	1	57	Park
Loyalsock Tp.	1	-	9	Park
Muncy Creek Tp.	8	-	8	Park
	235	36	209	

\*These disaster urban renewal projects were completely funded by U.S. Department of Housing and Urban Development and Pennsylvania Department of Community Affairs.

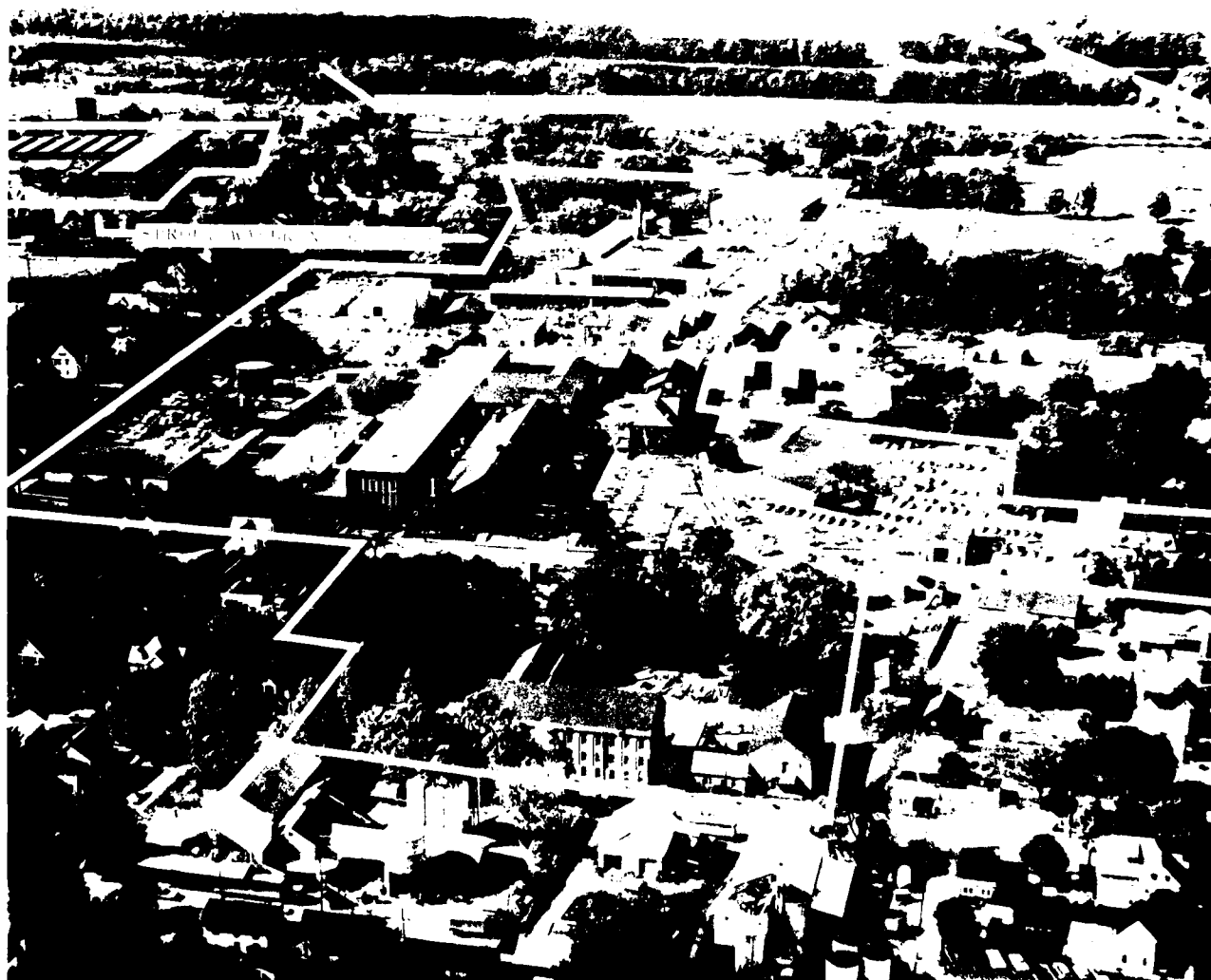


tion activities. Various office functions are also located there including the sales, advertising, design and development, engineering, production control, accounting and personnel departments. With 1,250 employees, Sprout-Waldron is a major employer in Muncy and the surrounding areas and the second largest employer in Lycoming County. Thus, it is a vital part of the county's economic base.

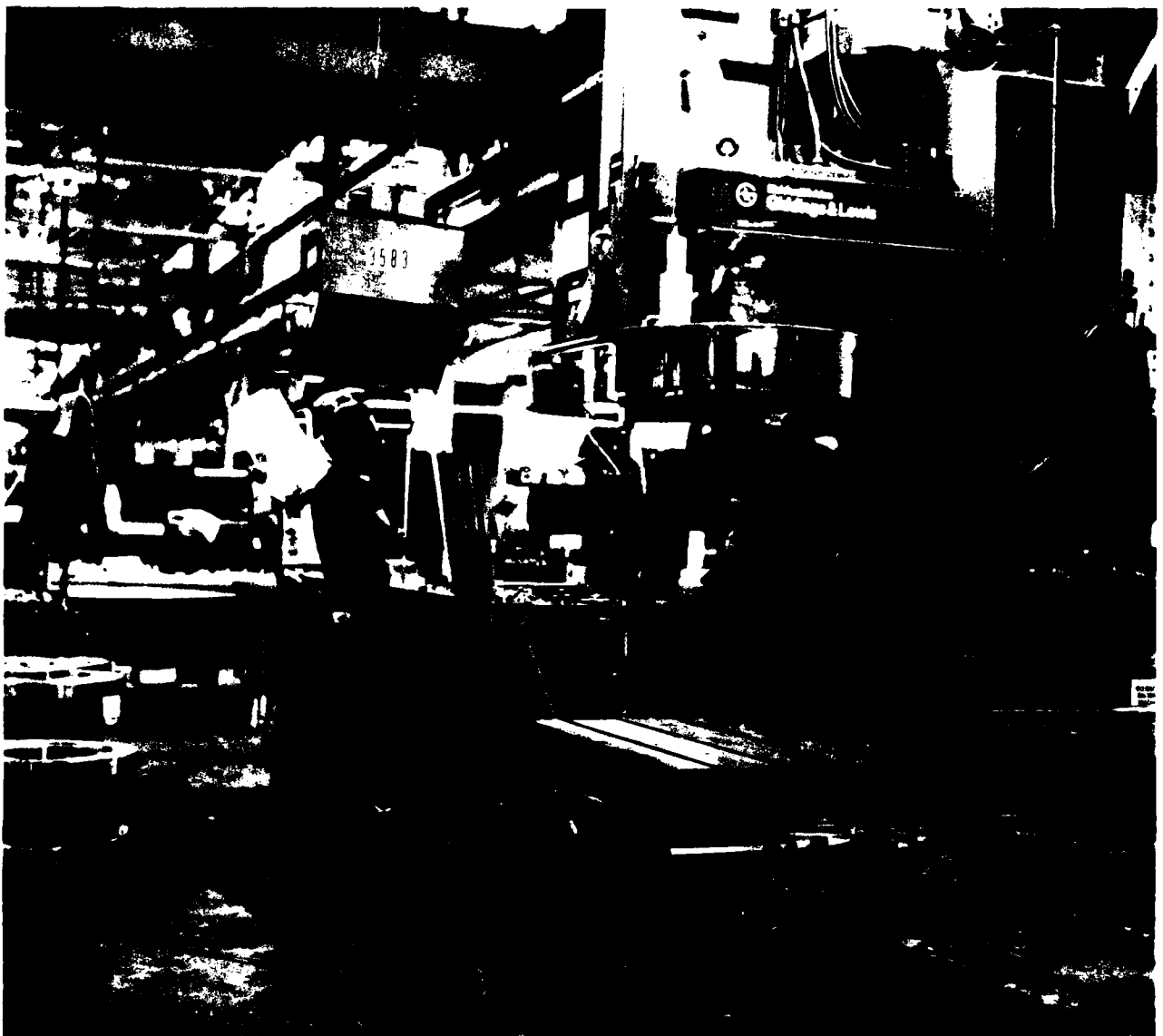
Sprout-Waldron's plant site consists of about 40 acres located on or near the floodplain of the West

Branch Susquehanna River and close to Muncy Creek. The site is located over the bed of an abandoned branch of the Pennsylvania Canal. Part of the site is flat while the remainder is rolling hillsides with relatively steep slopes.

The plant's physical facility consists of 26 major buildings totaling 600,000 square feet of floor space. The majority of these buildings are located on the flat lower portion of the site and are subject to flooding. Activities carried out in the flood-prone areas include iron and steel alloy treatment



*Sprout-Waldron Division of Koppers Company, Inc., located at Muncy, Pa. The plant consists of 26 major buildings on a 40-acre site. It represents a multi-million dollar investment.*



*Sprout-Waldron's plant includes valuable specialized equipment. Even minor flood damage would seriously affect plant production.*

operations, associated foundry operations, sheet metal fabricating operations, machine assembly, raw materials and machine parts storage, experimental laboratory and main company offices.

Sprout-Waldron facilities have been damaged eight times by floods between 1900 and 1980. Numerous other floods have occurred in which water came sufficiently close to causing damage that precautionary actions were

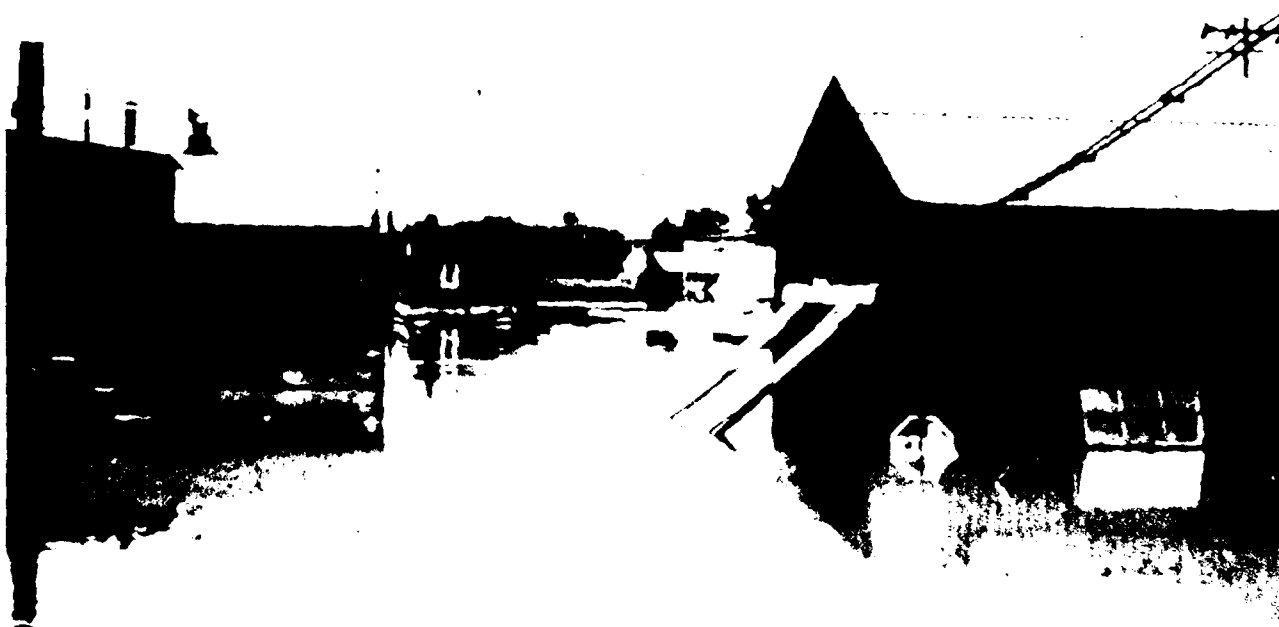
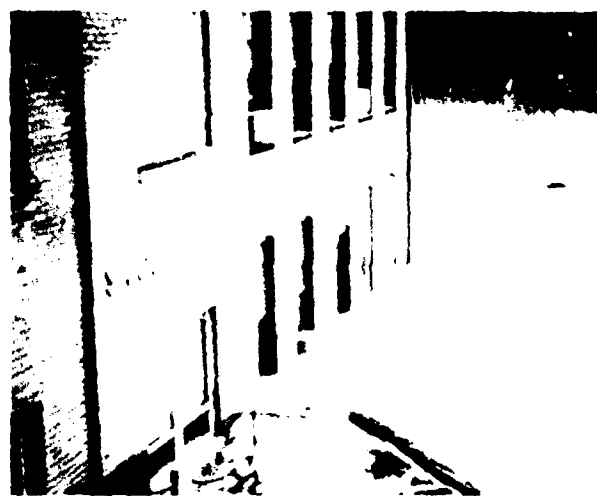
necessary. Past flood losses have included damages to structures and equipment, business losses stemming from interruption of production, costs for emergency actions, and costs for cleanup and recovery.

Flood damages sustained by Sprout-Waldron following Tropical Storm Agnes in 1972 were over \$420,000. In addition, emergency costs were estimated to be \$238,000. It took approximately 6 weeks to return the plant to

90-95 percent of full operation. An additional loss of \$500,000 was caused by this business interruption.

Complete relocation of Sprout-Waldron's facilities to a flood-free site was found to be impractical. All

of the buildings except the office building are industrial type structures. They are generally one story, with high ceilings (up to 40 feet). Many of the elder buildings are of wood frame and brick construction while the ones built in the last 25 years are



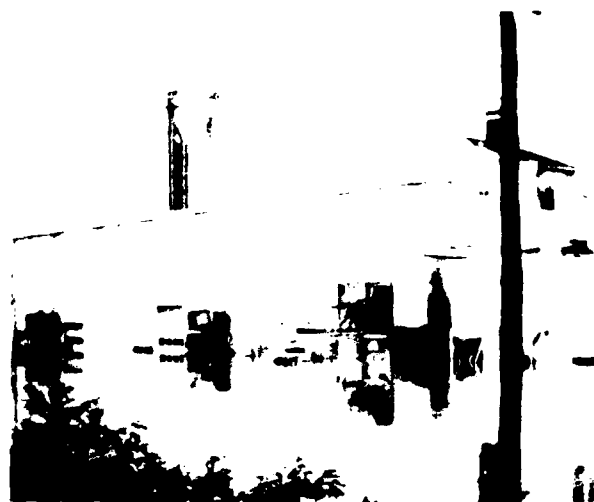
*Sprout-Waldron's plant was seriously damaged in 1972 by flooding from Tropical Storm Agnes. Damages, interruption to business and other flood-related losses totaled over \$3 million (1979 dollars).*

constructed with steel frames with masonry and or steel sided walls. The large brick structures are physically unsuited for relocation. The cost of abandoning the existing structures and constructing new buildings at a flood-free site was prohibitively expensive.

Realizing that other floods of the same or greater magnitude could be expected in the future, Sprout-Waldron investigated the potential for public construction of a levee, dike or dam system to protect the Muncy area. It was learned that post-Agnes investigations conducted by the Corps of Engineers found that a local flood protection project was not economically justified. An independent evaluation by the Pennsylvania Department of Environmental Resources confirmed the Corps analysis, citing poor soil conditions for levee systems as a major deterrent. Convinced that a public project to solve the flood problem was not forthcoming, the Sprout-Waldron management team developed it's own six part program to minimize future losses. The program was developed through conferences with supervisors and workers to identify problems and investigate potential solutions and costs. Items included in the program were:

- Permanent relocation of some operations to nearby flood-free sites as the need arose for additional space;
- Establishment of a system for early recognition and forecasting of floods on Muncy Creek and the West Branch Susquehanna River;
- Preparation of a formal plan for emergency evacuation of movable items;
- Continuation of floodproofing measures begun in previous years;
- Establishment of a reliable system for emergency communications; and
- Provisions for rapid recovery and restarting of production.

These points are discussed in the following paragraphs.



*Almost six weeks were required to return the Sprout-Waldron plant to 90-95 percent of full operation.*

## **Permanent Relocation of Activities**

A part of Sprout-Waldron's flood loss reduction program is to relocate facilities and operations to flood free areas when practical. New facilities constructed at safe elevations since the 1972 flooding include a metal heat treating facility, an air compressor building, a maintenance department spare parts building, plant engineering office and metallurgy laboratory. Equipment in each of these buildings would sustain significant damages if flooded. In addition, the spare parts and air compressor are essential to expedite post-flood cleanup and restart production operations. Compressed air is used extensively to clean and dry machinery which has been flooded. Most machinery is also operated at least in part by compressed air.

In 1979, Sprout-Waldron purchased a nearby industrial facility located at a safe elevation to house its machine shop which had been heavily damaged in past flooding. The flood-prone space in the former machine shop was converted to storage for semi-finished metal machine parts and other items not easily damaged by floods.

## **Flood Recognition and Forecasting**

The only flood forecasts available for the Lycoming County area at the time of Tropical Storm Agnes were those issued by the National Weather Service. Specific predictions of floods were usually made only for the West Branch Susquehanna River at Lock Haven, Williamsport and Lewisburg, with gage relationships established for other communities such as Muncy (at the Muncy-Montgomery Bridge). Only general statements concerning the probability of flooding were issued for other areas. The forecasting system and warning dissemination system operated slowly, leaving little time for protective action after a warning was received.

After Tropical Storm Agnes, Sprout-Waldron management decided to develop its own flood warning system to provide additional information and warning time. As a first step, Sprout-Waldron asked a National Weather Service cooperator living in Muncy to aid in establishing a flood warning system. With the assistance of the National Weather Service River Forecast Center at Harrisburg, a self-help flash flood warning system was eventually established on Muncy Creek. The system was based on reports of precipitation and stream levels provided by volunteer observers scattered throughout the watershed. Volunteers were drawn from friends and families of plant personnel and the system coordinator. Reports were telephoned to a coordinator operating out of an office at Sprout-Waldron. The coordinator then predicted the stream level for the West Branch Susquehanna River and Muncy Creek using formulas which related those levels to precipitation and runoff data in the Muncy Creek sub-watersheds and water levels at several points along the river upstream from Muncy. Information and data collected through the system was passed on to the NWS River Forecast Center by the system coordinator.

During flood-threatening events, Sprout-Waldron began hourly monitoring of the West Branch Susquehanna River and Muncy Creek to determine water levels and rate of rise as an indicator of impending flooding. The firm contracted with a private weather forecasting service to provide early notice of threatening weather conditions and confirmation of forecasts.

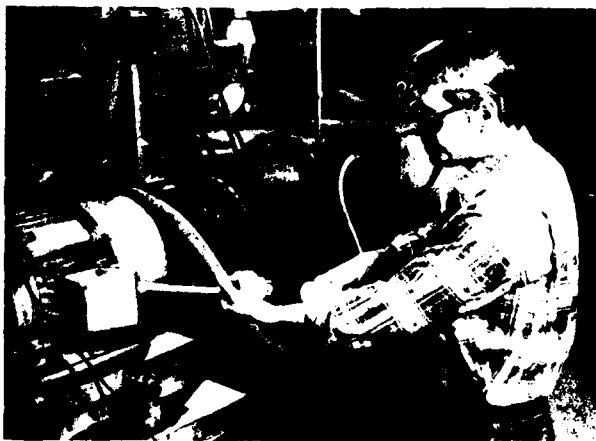
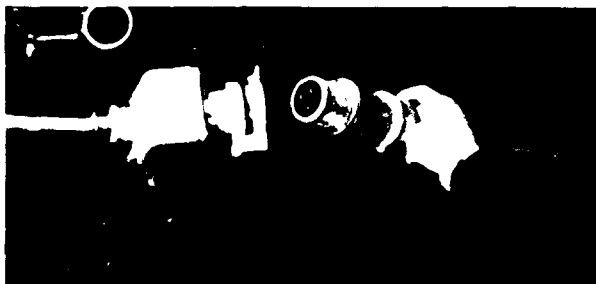
Sprout-Waldron's system worked well during Tropical Storm Eloise in 1975. For example, the crest level on the West Branch Susquehanna River at the Muncy-Montgomery Bridge was predicted several hours in advance to be 30.32 feet. The River actually crested at 31.19 feet.

Sprout-Waldron's flood warning system merged in 1977 with the Lycoming County flood warning system described in a later section of this chapter.

## Emergency Evacuation

Sprout-Waldron formulated and implemented an emergency evacuation plan to temporarily relocate many items subject to flood damage. The plan included provisions to reduce the time and cost for removing and reinstalling equipment and other items, and for transporting items to be relocated. The reduction in time requirements was achieved by modifying equipment and buildings and adopting procedures for storing raw materials and products. These modifications and procedures include:

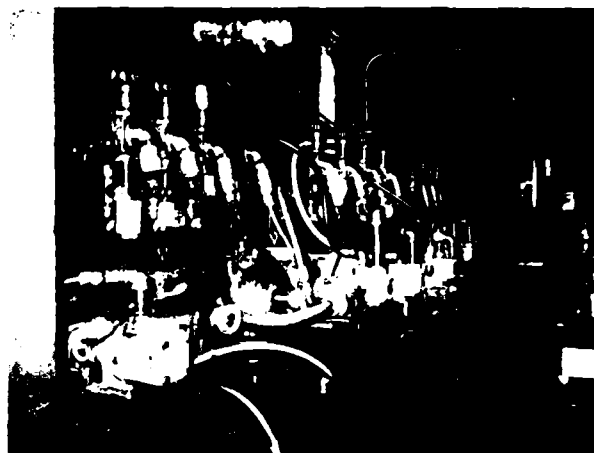
- "Quick disconnect" plug and receptacle sets have been installed on standard electrical motors so that disconnections can be made in a matter of seconds. This provision also enables rapid reinstallation of



*"Quick disconnect" electrical fittings enable rapid evacuation and replacement of equipment without skilled labor. They also facilitate routine maintenance and relocation of equipment.*

motors since only cleaning and drying of the receptacle is required after flooding and before electrical power is reconnected. It also eliminates the need for an electrician, allowing the same person unbolting the motor from its machine mountings to make the electrical disconnection. Elimination of requirements for special trades speeds up the emergency evacuation and facilitates better use of available manpower. The quick disconnect plugs and receptacles cost approximately \$180 per set.

- Motor-pump units have been equipped with quick disconnect fittings on both suction and discharge lines as well as on electric power lines.



*Lines to and from these pumps are equipped with quick disconnect plumbing fittings. Motors are equipped with quick disconnect electrical fittings. The chain hoist on the overhead track is used to load pumps and motors on a truck for evacuation during floods.*

- Complex electrical wiring which could not be conveniently equipped with a quick disconnect plug and receptacle set has been prepared for emergency disconnection and post-flood reconnection. Preparations consist of labelling each wire with water proof tags. This has the advantage of both speeding the reconnection of equipment and avoiding errors.

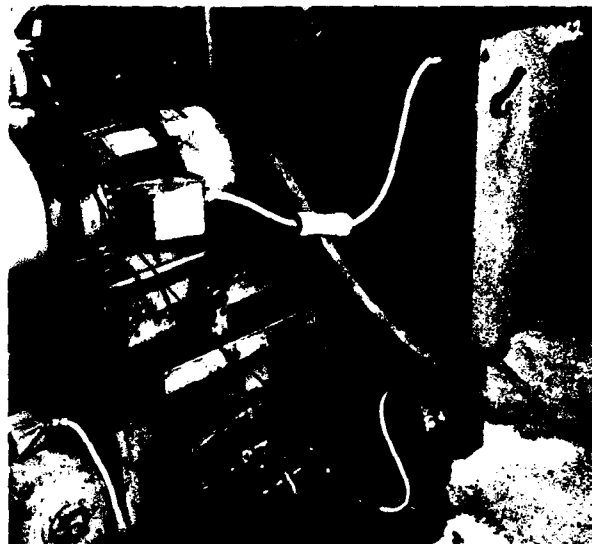
- The electrical distribution system serving the plant facilities have been redesigned and modified to enable electrical power to be shut off as various areas become flooded. This also enables each area's activities to be restarted as soon as flood waters have receded and the electrical system has been checked. The overhead electrical distribution system is less subject to damage and requires little or no effort for cleanup.
- All doors which are normally operated electrically have been equipped with standby provisions for manual operation in the event electrical service is disrupted. The ability to open doors is essential for relocating equipment and equalizing water pressures to prevent damages.
- Identification numbers have been painted on machines and their removable parts such as motors and



*Addition of manual openers ensures doors can be opened if electrical power fails. Doors must be opened during floods for evacuation of equipment and to allow equalization of water depths inside and outside of buildings. This door was added to enable rapid evacuation of equipment and other building contents.*

electrical controls. This facilitates the rapid and correct reassembly of equipment after a flood.

- Motor-generator sets and motor-pump units have been mounted on skids to facilitate movement by fork lift trucks and to enable sliding equipment out of and into tight places.

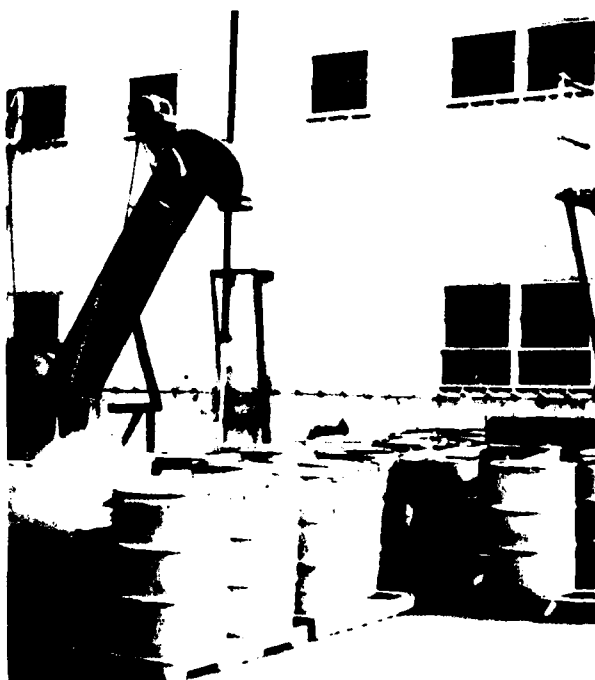


*Identification numbers painted on equipment to be evacuated enables its rapid reassembly after a flood.*

- Large equipment items which require lifting by an overhead crane or fork-lift truck have been fitted with lifting bars or lugs. This eliminates time which would otherwise be required for rigging. Equipment has also been placed to enable easy access for lifting.
- Perishable plant inventory is stored on pallets wherever possible to improve the speed of removal using fork-lift trucks.
- Aisles, doors and halls in first floor offices have been laid out wide enough to accommodate equipment designed to move desks and files. The sizes of desks, tables and files have been standardized to permit easy removal.



*Lifting rings and bars attached to equipment speeds evacuation by eliminating rigging time.*



*Raw materials, supplies and finished products were initially stored on pallets to enable faster evacuation in the event of a flood.*



*A truck level exit at Sprout-Waldron's main office permits evacuation of office equipment, furniture and files. As shown in the interior view, such modifications can be attractively incorporated into the office decor.*

- Overhead doors and dock loading areas have been designed wherever possible to accommodate the trucks which transport equipment. An exit through an existing office window has also been modified to serve as a loading dock for the removal and loading of office equipment.

A small levee was constructed at a low point where water from Muncy Creek or backwater from the West Branch Susquehanna River first enters company property to provide an additional 2 hours for evacuation.



Plant management undertook development of a comprehensive plan to guide emergency evacuations. A detailed study was made of the plant's flood-prone areas and interviews were conducted with employees and supervisors involved in previous flood episodes at the plant. Items that cost the most to repair and/or which caused the longest delays in restarting production were identified. It became apparent during this investigation that the key information needed to guide evacuation was that concerning:

- Supervisor responsible for area or building;
- River level required to flood lowest spot of each area or building;
- River level at which each building or area becomes isolated (Several buildings are constructed on slightly raised foundations).
- Minimum number of hours required to evacuate preselected items from each area;
- Key items to be removed and priority in which these items should be evacuated;
- Time evacuation should start;
- Number of laborers required to evacuate each area;
- Number of electricians and other key crafts required for each area;
- Number of flat bed semi-trailers required for items that are not damaged by rain, sleet or snow, and for items loaded by fork-lift trucks in areas not equipped with loading docks.
- Number of van trailers required for each area for items susceptible to damage by weather;
- Number of fork-lift trucks required in each area to load equipment;
- Any special instructions that are important for orderly evacuation and

storage of items from a particular area.

- A system of tagging each truck evacuating equipment with information on the building and door to which it should be returned.

As the details of the evacuation arrangements were designed, the plan was prepared in written form. It was initially organized as a sizable narrative report, then successively revised to reduce its length and complexity. This process led eventually to formulation of the evacuation plan as a condensed chart containing only the key information needed to guide emergency actions. Figure 6 shows the chart. Using the rate of rise of the river, river elevation and number of hours needed to evacuate a given area, it can be quickly determined at what time evacuation must start to have the area cleared before flooding begins.

The general sequence of activities leading up to and through an evacuation is as follows:

- The plant engineer maintains a continuing watch on potential flood conditions through information provided by the NWS and the private weather forecasting service employed by the company.
- The network of precipitation and stream level observers is activated by the County whenever conditions indicate the potential for flooding. Data are gathered and flow predictions provided to the company. The company also stations its own staff at the river to make hourly or more frequent reports on water level.
- Data collected on stream conditions are plotted by the plant engineer to indicate the current level of the river, rate of rise, and predicted crest height. Daily briefings are held with the company management team. As conditions approach a point necessitating evacuation, supervisors are notified to remain available and nearby truck terminals are alerted that trucks may be required.

FIGURE 6. SPROUT-WALDRON EVACUATION PLAN.

DEPARTMENT OR BUILDING	EXP. LAB	PATT. SHOP	PELLET DIES	CASTING CLEANING	FOUNDRY	ADVERTISING ALTMANS	OFFICE	EST. TOTAL <sup>a</sup>
BUILDING NUMBER(S)	LAB NO. 73 NO. 4, NO. 74A, NO. 75	NO. 77, NO. 87, NO. 3	NO. 70, NO. 70A, NO. 70E	NO. 26A NO. 26B NO. 26D NO. 26E	NO. 89 NO. 89A NO. 88 NO. 50	NO. 93	NO. 1, NO. 1A NO. 1B	
SUPERVISOR AND OR COORDINATOR	R. B. COLLIER	N. P. HEINCELMAN	H. L. MILHEIM	J. L. HOLLIDAY	S. J. MANN	H. L. WEBSTER	W. G. TRAPP W. D. CAPTY	
FEET OF WATER REQ'D TO FLOOD FIRST FLOOR	36	26 TO 27	27 TO 27-1/2	26 TO 27	31-1/2	31	31-1/2	
ISOLATED AT (FEET OF WATER)	27	26 TO 27	26	27	26 TO 27	27	27-1/2	
ADVANCE WARNING REQ'D (IN HOURS)	12	9-1/2	9	8	6	6	2	
ORDER OF EVACUATION		1. PATTERN STORAGE BLDG. NO. 872 2. PATTERN STORAGE BLDG. NO. 77 3. PATTERN SHOP BLDG. NO. 3	1. VARI-DYNES AND PANELS 2. OIL PUMPS 3. PUMP-GIL 4. MOTORS 5. HEAT PLANT 6. FINISHED DIES 7. INSPECTION TOOLS		1. RED SHED EXOTHERMAL HEADS 2. RIN DOWN CHANNEL 3. MOTORS 4. PUMP THE CHANNEL			
START EVACUATION (TIME)								
MEN REQUIRED	5	25	25	8	30	12	40	251
ELECTRICANS REQ'D	NONE	NONE	AS MANY AS AVAILABLE	YES	YES	NONE	NONE	
FLAT BED TRAILERS REQ'D	NONE	NONE	3	NONE	1	NONE	NONE	16
VAN TRAILERS REQ'D	NONE	5	1	NONE	3 TO 4	NONE	NONE	20
FORK LIFTS REQ'D	NONE	1	3	1	2 OR MORE	NONE	NONE	
NOTES	EVACUATE BASEMENT SOON AS POSSIBLE TO THIRD FLOOR	NEED TWO ROLLS PLASTIC FROM LUNDY'S TO COVER PATTERNS IN PARKING LOT ON HILL	LOAD ONE FLAT BED AT WEST DOOR, ONE AT THE NORTH DOOR ONE AT THE EAST DOOR, AND THE VAN AT THE NORTH DOOR	MOVE EQUIPMENT TO PARKING LOT ON THE HILL.	LOAD FLAT BED AT SOUTH RAMP AND/OR SOUTH YARD. VANS NEED PORTABLE DOCK. ALL SAND CARS MUST BE MOVED.	ONE STAKE BODY TRUCK AND ONE PICK UP ARE NEEDED. STORE MATL. IN WELDON BLDG.		CECIL LAURENSEN OBTAIN REQUIRED TRUCKS. L. F. SHADDOCK COORDINATE TRUCK SPOTTING THROUGH-OUT PLANT

<sup>a</sup>Totals do not add because requirements for evacuation of all buildings are not shown in chart.

- A decision to evacuate is made when data indicates flooding will begin within 12 hours, which is the approximate time required to complete the evacuation. Supervisors are notified to call their crews and report for work. Trucks needed for evacuation procedures are ordered. An accounting number for all costs related to the flooding is established at this time to facilitate preparation of insurance claims.
- Buildings are evacuated in a sequence based on the estimated length of time remaining before each floods and the length of time required to complete the evacuation. Each truck load of material is tagged with a number corresponding to the particular building and door to which it is to be returned and moved to a nearby schoolyard out of the floodplain. Projections of flooding are made on a continuing basis to determine the need for continued evacuation.
- Electrical power is shut off in each building as its evacuation is completed. Doors of evacuated buildings are left open to permit the entrance of water, and fire fighting equipment is removed.
- Facility clean-up is begun as soon as waters recede below the floor level of each building. Clean up includes a preliminary safety inspection, restoration of electricity, hosing down of structures and cleaning of equipment not evacuated.
- Items evacuated are returned to their appropriate locations and reconnected.

Photographs are taken throughout the evacuation process, the flood period, cleanup and return to operation. The photographs are used to document insurance claims.

## **Floodproofing**

Equipment and facilities at the Sprout-Waldron plant which cannot be readily evacuated are protected from flood damage in a variety of other

ways. These include elevation of equipment above expected flood levels and anchoring of floatable items. Specific adjustments or procedures which have been implemented include the following:

- High and low voltage electrical services, transformers, and in-plant electrical distribution gear have, where practicable, been located 5 feet above the 100-year flood level, including emergency lighting systems.

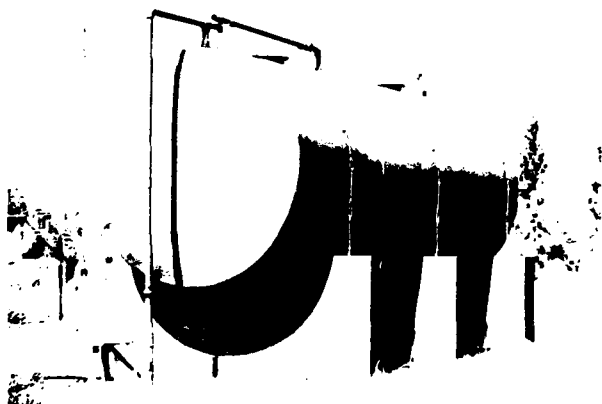


*Elevation of transformers eliminates one cause of electrical power failure during floods.*

- Primary and emergency service utilities including boilers, air compressor, fire pump for sprinkler system, bulk fuel storage tank, air handling and air pollution control units have been placed above the 100-year flood level.
- A bulk liquid storage tank located in the floodplain has been fastened to anchors capable of resisting more than twice the buoyant force of an empty tank.
- Buried bulk liquid storage tanks have been equipped with water tight fill caps and vent pipes that extend five feet above the 100-year flood level.



*Electrical system components are elevated throughout the Sprout-Waldron plant. Service to low areas can be shut off when flooding occurs while still maintaining power for emergency lighting and other functions through this elevated system.*



*This liquid bulk storage tank is anchored to prevent flotation during floods. Cables and anchor blocks are designed to resist twice the maximum buoyancy of the tank.*

- Telephone and paging system distribution equipment has been located above the 100-year flood level.
- All valuable record storage facilities have been located above the 100-year flood level.
- Standby closed tanks and high volume pumps have been provided to enable rapid transfer of process liquids from open top tanks. This allows the open top tanks to be filled with water to neutralize buoyancy and avoid damage.
- Many wooden floors damaged in previous floods have been replaced with concrete slab floors which are resistant to damage and are easily cleaned.
- Standby electrical generators operated on propane have been located above flood levels to ensure availability of power for post-flood cleanup activities.



*Emergency utility water pumps are located on platforms well above flood level. This ensures availability of water for cleanup in the period immediately after a flood.*

- Propane tanks for emergency electrical generators have been elevated above flood levels.

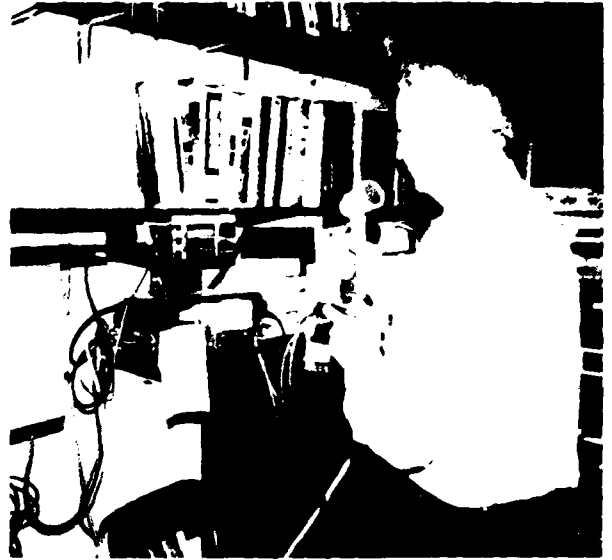


*Propane tanks for Sprout-Waldron's emergency generators are on platforms above flood level.*

## **Emergency Communications**

Past flood experience demonstrated the inadequacy of telephone communications because of the fixed location of stations and disruptions of service. Sprout-Waldron managers decided a more reliable and flexible communications system was needed to coordinate emergency activities at the plant and to communicate with emergency management officials and others. An FM radio system was selected for these purposes because of its ability to operate inside buildings with metal siding and roofs. Radio equipment obtained included a 25 watt, 2-channel, base station equipped with a 60 foot hi gain antenna; and 12 portable hand-held units with a range of 1-3 miles. One channel of the base station operates on a frequency assigned to Sprout-Waldron and the other on a local government frequency (154.980 MHz) assigned to the County. The company also supplied the National Weather Service office located at the Williamsport-Lycoming County

Airport at Montoursville with a base station operating on the County frequency. Provision of this radio enabled a three way link between Sprout-Waldron, the Lycoming County Emergency Management Agency and the National Weather Service. The radio system is tested weekly.



*An FM radio system provides emergency communications throughout the plant and with the National Weather Service and the Lycoming County Emergency Management Agency.*

## **Recovery**

The major losses resulting from the 1972 flooding stemmed from post-flood down time. Adjustments and procedures which facilitate faster return to operation include storage of items required for clean up, provisions to ensure the availability of electrical power, and prompt initiation of clean up activities.

Since floods in the area affect a large number of homes and commercial establishments, items needed in the immediate post-flood period are in short supply. To overcome problems of availability, Sprout-Waldron maintains a rotating stock of supplies stored

above flood level including: flashlight batteries, spare parts, cleaning materials (mops, squeegees, hoses, and solvents) electrical tape, electrical contact cleaner, and tools.

Electrical power in the immediate post-flood period is essential for draining pits, washing down equipment and buildings, lighting and other purposes. To ensure the availability of power, emergency generators are located on wall-mounted platforms above flood levels. The generators operate on propane gas which is also stored above flood levels, outside of buildings.

Clean up is begun immediately after flood waters recede below floor levels. An artesian well and volunteer fire company tank trucks are used as sources of water required for flushing sediment and debris from machines and buildings before it dries to a hardened crust.

## Effectiveness

Sprout-Waldron's adjustments to floods are part of an ongoing program. Some of the adjustments noted in the preceding section were made prior to the flooding in 1972 but the larger number were made as part of the repair and rehabilitation of the plant complex following that flood. Still further adjustments have been made since that time and others are planned for the future including relocating additional portions of the in-plant electrical systems above flood levels.

An explicit analysis of the cost effectiveness of the adjustments cannot be made because all of the costs associated with various adjustments are not identifiable. However, a gross indication of effectiveness can be obtained by comparing the losses from the 1972 flood to the losses caused by Hurricane Eloise in 1975.

The major modifications completed in the period between the 1972 and 1975

floods included installation of electrical quick disconnects; anchoring, capping and venting of bulk fuel tanks; and about half of the modifications to speed evacuation. The cost of adjustments during this period was approximately \$30-40,000.

Table 5 compares the circumstances and losses of the 1972 and 1975 flooding. As shown, the 1975 flood level was lower than that experienced in 1972. However, differences in the damages experienced in the two floods cannot be attributed to any great extent to the difference in flood levels. A large proportion of the direct damage to equipment takes place in the first few feet of flooding and the higher level reached by floodwaters in 1972 only increases damages by a small amount. In addition, the major source of loss is the interruption to business. This type of loss is far more dependent on the time required to clean up and restart production than on the depth or duration of flooding.

As shown in Table 5, total losses in 1975 were notably less than those experienced in 1972. In 1979 dollars, \$3,152,587 or 93.2 percent of the losses incurred in 1972 were avoided in 1975. This order of magnitude in flood losses reduced was evident in both the physical damage category (98.4%) and the business interruption category (93.6%). Emergency costs were reduced by 83.2%. The proportion of loss distribution shifted between floods. While business losses remained the dominant loss; in 1975 emergency costs exceeded physical damages sixfold. This contrasts with the 1972 flood when emergency costs were two-thirds less than physical damages.

The fact that the significant reductions in losses are attributable to the adjustments made between floods by Sprout-Waldron and not to differences in flood height can be illustrated by comparing the ratio of 1975 and 1972 losses for the Borough of Muncy with the ratio of losses at Sprout-Waldron.

TABLE 5  
COMPARISON OF 1972 and 1975 FLOODS  
AT SPROUT-WALDRON

Flood Events			
<u>Item</u>	<u>June 1972</u> <u>"Agnes"</u>	<u>September 1975</u> <u>"Eloise"</u>	<u>Percentage</u> <u>Difference</u>
<u>Warning System Existing</u>			
National Weather Service	Yes	Yes	-
Sprout-Waldron	No	Yes	-
Lycoming County	No	No	-
<u>Flood Conditions</u>			
Peak elevation <sup>a</sup>	37.45'	31.19'	16.7
Depth of flooding <sup>b</sup>	15.75'	0.58'	30.1
Duration of inundation <sup>c</sup>	24 hrs.	20 hrs.	16.0
<u>Length of Shutdown</u> <sup>d</sup>	42 days	3 days	92.8
<u>Losses</u> <sup>e</sup>			
		<u>% of</u> <u>Total</u> <u>Losses</u>	<u>% of</u> <u>Total</u> <u>Losses</u>
Physical damages	\$744,280 (22.5%)	\$11,963 (5%)	98.4
Emergency costs	\$491,843 (14.5%)	\$82,431 (36%)	83.2
Business Inter- ruption losses	<u>\$2,147,500 (63.0%)</u>	<u>\$136,708 (59%)</u>	93.6
Total Losses	\$3,383,680 (100%)	\$231,102 (100%)	93.2

<sup>a</sup>At Muncy-Montgomery Bridge, 150 yds. from western edge of plant site.

<sup>b</sup>At Pattern Shop and pattern storage area.

<sup>c</sup>Length of time that Pattern Shop and pattern storage area were inundated.

<sup>d</sup>Until operation resumed at 90-95% of capacity.

<sup>e</sup>In 1970 dollars. Based on the Consumer Price Index (all prices, all urban areas) as reported by the Bureau of Labor Statistics, Department of Labor, multipliers of 1.735 for 1972 and 1.349 for 1975 prices were used to inflate damages reported to 1970 dollars. Calculations of 1970 damages by Sheaffer and Roland, Inc.

Results of this comparison are shown in Table 6. The ratio of 1975 to 1972 losses at Sprout Waldron, is 0.068, much lower than the comparable ratio of .328 for the Borough of Muncy. This result shows that 1975 flood losses at Sprout-Waldron were a far smaller proportion of 1972 losses than was the case for the Borough of Muncy and suggests that the lowered flood losses at Sprout-Waldron were not merely the consequence of a lower flood event.

Assuming the same ratio of 1975 to 1972 losses existed between Sprout-Waldron and the Borough of Muncy, Sprout-Waldron losses in 1975 would have been \$1,100,850 without the implementation of preparedness measures. Given that assumption, the savings to Sprout-Waldron in the 1975 flood due to the \$30-40,000 of adjustments made in the period between 1972 and 1975 would have been \$877,748, approximately 25 times the cost of the

adjustments. The value of this investment will increase as the adjustments continue to reduce damages in future floods.

A near-flood in 1979 resulted in Sprout-Waldron initiating emergency actions to relocate equipment and other items. The emergency effort was terminated after several hours when it became apparent that waters would not reach a damaging level. The company filed an insurance claim with the National Flood Insurance Program and was compensated \$10,520 for a portion of the cost of the emergency action.

The adjustments made by Sprout-Waldron have proven to have benefits beyond reduction of flood losses, including:

- Use of electrical quick disconnects eases the problems of rearranging equipment, changing work stations, and replacing equipment.

TABLE 6  
REDUCED FLOOD LOSSES AT SPROUT-WALDRON  
COMPARED WITH THE BOROUGH OF MUNCY, PA, 1972 and 1975 FLOODS

<u>Flood Losses<sup>a</sup></u>	<u>Sprout-Waldron, Inc.<sup>b</sup></u>	<u>Borough of Muncy<sup>c</sup></u>
1975 (Tropical Storm Eloise)	\$ 231,102	\$11,886,485
1972 (Tropical Storm Agnes)	\$3,383,689	\$33,903,750
Loss Ratio $\frac{(1975 \text{ losses})}{(1972 \text{ losses})}$	0.068	0.328

<sup>a</sup>It was assumed, based on interviews at Sprout-Waldron, Inc. and Borough of Muncy, PA officials, that the company's property value increased at the same or greater pace than the Borough's. This assumption eliminates the possibility that growth in the Borough's floodplain would affect the results of the test.

<sup>b</sup>In 1979 dollars. Based on the Consumer Price Index (All Prices, All Urban Areas) as reported by the Bureau of Labor Statistics, Department of Labor, multipliers of 1.735 for 1972 and 1.349 for 1975 prices were used to inflate damages reported to 1979 dollars. Calculation of 1979 damages by Sheaffer & Roland, Inc.

<sup>c</sup>Borough of Muncy damages as reported in Borough of Muncy, Pennsylvania, Flood Damage and Protection, prepared by Sprout-Waldron and presented to Congressman Schneebeli and the U.S. Army Corps of Engineers. November 24, 1975, page 2.



- The FM radio system provides for continuation of at least some in-plant communications during scheduled or unexpected outages in the area's electrical system.
- Emergency generators provide for some power during electrical outages and, in conjunction with pumps, improve fire fighting capability.
- Maintenance and repair of equipment is eased both by the lift bars and rings on equipment and by the identifications painted on items.
- Use of pallets to store items to be evacuated in an emergency led to a more efficient materials handling procedure.
- Quick disconnects reduce the need for plumbers and electricians in routine movement of pumps and motors.

Sprout-Waldron's participation in the flood warning system also pays dividends. Because of the relatively long time required to evacuate items from the plant, emergency actions must begin several hours in advance of actual flooding. Accurate early prediction of flows makes it possible to avoid initiating costly emergency actions unnecessarily.

## Maintenance

The flood adjustments implemented by Sprout-Waldron require minimal maintenance. The major activity required to maintain the viability of the adjustments is periodic review of the response plan by the management team and the staff charged with maintenance and enhancement of flood preparedness arrangements. Sprout-Waldron's procedure is to review the program annually with supervisors and after each flood or near-flood experience in order to make improvements and decrease the time required to carry out the plan the next time its use is required.

## Lycoming County Flood Warning System

The interest on the part of local officials which led to the establishment of Lycoming County's present flood warning system dates from the June 1972 flood. Prior to that time, the County's part-time civil defense director disseminated warnings received from the National Weather Service (NWS) River Forecast Center at Harrisburg and any information received from upstream areas. No explicit system existed for either the local collection or dissemination of flood related information.

## Prediction and Warning Problems

The severe flooding in 1972 exposed the weaknesses in national provisions for flood prediction and warning. The extensive flooding throughout the northeast tested the system severely. The National Advisory Committee on Oceans and Atmosphere (NACOA), a presidentially appointed oversight committee, evaluated the forecasting-warning-dissemination system following Tropical Storm Agnes. They reported:

"The National Warning System is not geared--and could not be--to exceptional storms like Agnes."

They said that if the performance had been letter perfect, there would still have been prodigious property damage. They added this caution:

"The issuance of accurate and timely warnings is only the beginning. There must also be a reliable system for delivery, a civil preparedness organization to cope with emergencies, and public understanding and response commensurate with the threat."

In the case of Tropical Storm Agnes in Pennsylvania, NACOA found that river forecasting had many problems.

Flash floods occurred on top of main stream floods or vice versa. In others, deluges washed out gages and interrupted communications. Radar coverage was found to be inadequate or not used consistently. Forecasts of precipitation amounts were faulty. Communication systems were saturated and telephone lines failed. The NACOA panel found that the circumstances which combined to create the problem were the unexpectedly great amounts of rainfall, vulnerability of data collection and transmittal systems to damage and disruption by the very rain and flood it was established to observe, and a processing system for forecasting which was designed for a pace to meet the onset of a river flood--not the onset of a flash flood. They found that the confusion between flash floods and river floods caused erratic response to river flood warnings issued after flash flood water began to recede. Even in Pennsylvania where there was a good civil defense program, people in the threatened communities were not aware of their vulnerability to flash floods.

The NWS operates a network of radar stations throughout the United States with an effective range of 125 nautical miles. Their value in detecting and tracking severe storms has been great, but their use in measuring quantitative precipitation is in an early stage of development. During Agnes, Lycoming County was in a gap area and not adequately covered by any of the NWS radar. Today, radar at Binghamton, New York and Harrisburg, Pennsylvania do provide areal coverage in north central Pennsylvania for at least high altitude storms.

## **Origin of System**

Available information on current and predicted flood heights in Lycoming County during the 1972 flooding was grossly inadequate. County and municipal officials did not have reliable data on which to base decisions. This problem was compounded by the lack of formal flood warning procedures which resulted in considerable internal

confusion. The one stream gage which was immediately available to local officials was a remote reading gage located on the West Branch Susquehanna River at Williamsport. That gage malfunctioned at the height of the flood, reporting falling stages while direct observation of the river showed it was continuing to rise. In the absence of reliable and detailed information, local officials were unable to quickly determine whether water levels were rising or falling at a particular time, how rapidly they might be rising or falling, and, consequently, the need to undertake or continue evacuation and other response actions.

Modernization, improvement, and expansion of the Lycoming County Emergency Communication System began in 1976. The new system was developed to establish effective Emergency Medical Services communication links between ambulances and hospitals using a radio/phone patch through a 24-hour communication center. SEDACOG, with a grant from the Appalachian Regional Commission, developed this system for a 10 county area in central Pennsylvania. With the installation of the sophisticated system and the Emergency Communications Center, the County found the operation of a flood warning system to be a logical extension of that program.

The initiation of the Lycoming County flood warning system can be traced to several sources. Key management personnel from Sprout-Waldron informally contacted Lycoming County Commissioners to encourage creation of a county flood warning system. A briefing given by NWS personnel to the SEDACOG Planning Coordinating Committee (a group of county planning directors) described technical assistance and equipment that it could make available for self-help volunteer systems. Soon after the 1975 flooding, representatives of the National Weather Service, Susquehanna River Basin Commission, Lycoming County Department of Emergency Services, and Lycoming County Planning Commission met with the County Commissioners to recommend development of a county-wide flood warning system.

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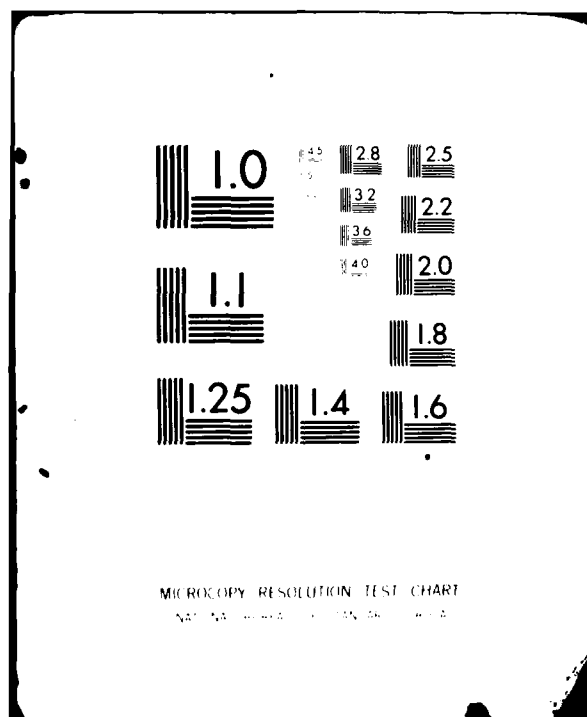
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*Lycoming County's Emergency Communications Center and Emergency Operating Center are located together. Incoming data and outgoing flood predictions can be handled rapidly and without confusion.*

The County Commissioners supported the recommendation and assigned responsibility for development to the Planning Commission. The Commissioners gave a strong mandate for development of the system but specified that it should be capable of independent operation on a local basis.

The Lycoming County flood warning system was established through a cooperative effort of the federal, state and local governments, private business and concerned citizens. The NWS provided metal tapes for staff gages, rain gages for use by volunteer observers, assisted in identifying appropriate locations for the gages, trained observers and established a

forecasting procedure. Close liaison was established between the flood warning system and the NWS office at the Williamsport-Lycoming Airport, located at Montoursville, Pennsylvania. Support, encouragement and advice on system organization were provided by the Susquehanna River Basin Commission.

The County coordinated the installation of the stream gages with the Pennsylvania Department of Transportation which agreed to survey each of the sites for staff gage installation. At the same time the Planning Commission was recruiting rain and staff gage observers throughout Lycoming, Sullivan and Tioga Counties. Over 100 people were contacted through watershed associations, township supervisors, civic groups and church organizations.

County staff approached those businesses and industries in the area who would derive direct benefits from the system. One industry provided the boards on which to mount the staff gages, another creosoted them, another provided poles on which to mount some



*Staff gages installed throughout the county by county personnel enable measuring high flows. Measurements are used in predicting downstream floods.*

of the gages, and another provided technical assistance on how to mount them. Still another local firm provided paint and brushes to paint the gages. Soon, with help from County employees in the Comprehensive Employment and Training Act (CETA) program, the system was completed. Within three months of the first meeting, an organization and system had been developed to provide adequate information to predict minor, moderate, or major flooding on the six main tributaries of the West Branch Susquehanna River.

The out of pocket cost for materials used in establishment of the warning system was \$500. The cost of operation in successive years is shown in Table 7. The amounts shown include wages for staff time, purchase of equipment, an annual banquet for volunteers and other associated costs.

TABLE 7  
COST SUMMARY  
LYCOMING COUNTY FLOOD WARNING SYSTEM

Year	Times Operated	Cost
1977	4	\$4,082
1978	6	\$3,359
1979	8	\$7,135
1980	2	\$1,113

## Description

The County's present flood recognition system consists of approximately 85 volunteers who serve either as observers or observer alternates. The observers and alternates are organized

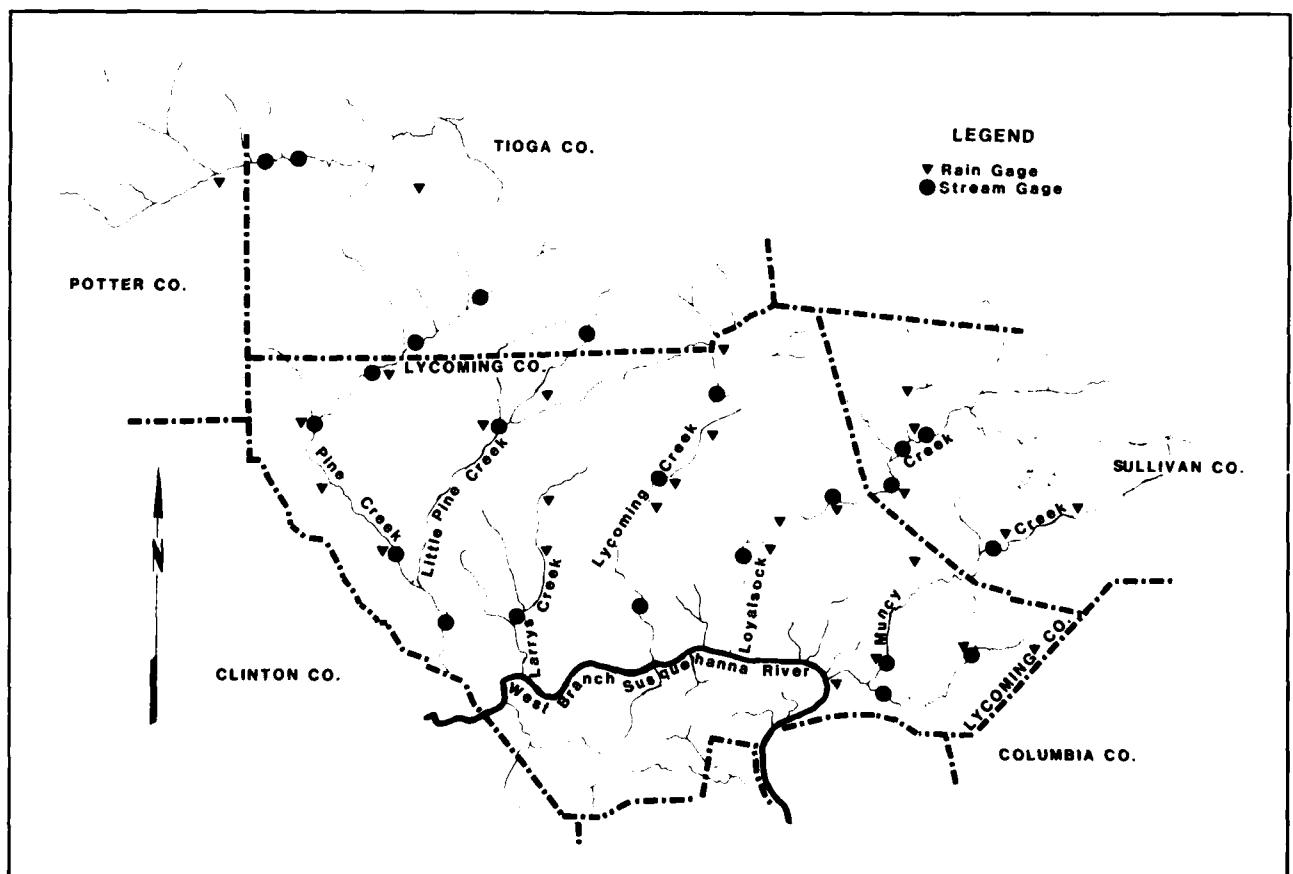
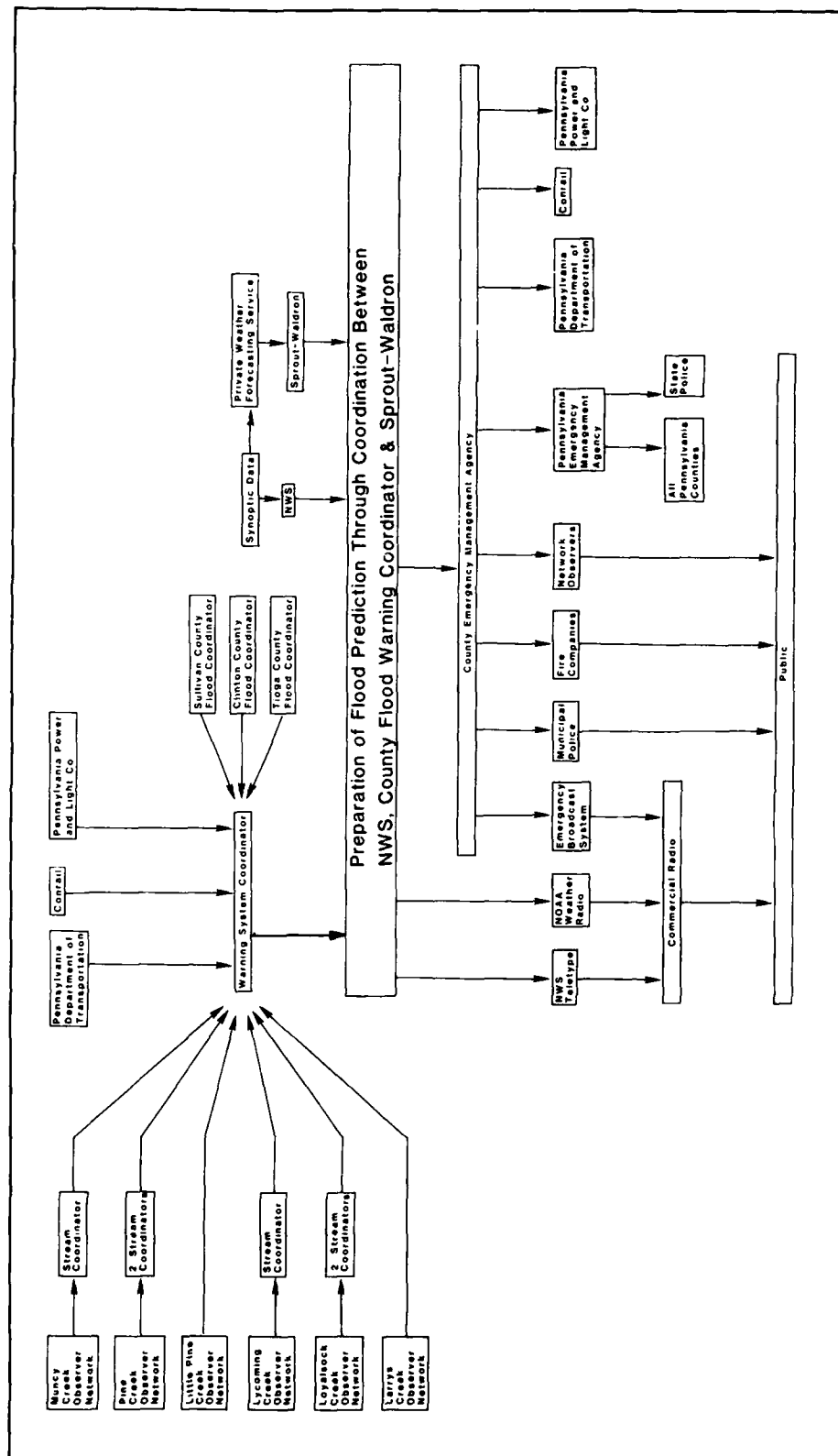


FIGURE 7. POINTS OF PRECIPITATION AND STREAM LEVEL MEASUREMENT FOR LYCOMING COUNTY FLOOD WARNING SYSTEM.



into separate data collection networks for Muncy, Pine, Little Pine, Lycoming and Loyalsock Creeks. Each network of observers is supervised by a "stream coordinator". Figure 7 shows the principal locations where information is collected on rainfall and stream levels. There are also numerous monitoring sites along Pine Creek in Tioga County. Figure 8 illustrates schematically the operation of the flood warning system.

Headquarters for the flood warning system is the office of the Lycoming County Emergency Management Agency, located adjacent to the emergency communications center. The headquarters is equipped with telephones, maps and both radio and teletype communications. Staffing of the headquarters during floods consists of the Warning System Coordinator, assistants, and volunteer radio operators who provide liaison with amateur radio units if their assistance is requested. All participants have alternates to provide 24 hour operation for several days.

The flood warning system is activated whenever an observer or network coordinator contacts the County Emergency Management Agency with information that a location has received a prescribed amount of rainfall (1 inch in 12 hours during the winter or 2 inches in 12 hours during the remainder of the year). It is also activated whenever the NWS or the private weather forecasting service employed by Sprout-Waldron forecasts conditions which could lead to flooding. The system coordinator is reached by a pocket size radio monitor and tone alert pager. All observers are then contacted and requested to make hourly reports on rainfall and/or stream levels.

Precipitation data and stream levels are collected by observers and reported to the stream coordinator. After consolidating data from observers in their area, stream coordinators report to the warning system coordinator. Based on the information received, the flood warning coordinator determines an average rainfall for each of

the County's major watersheds and prepares flood forecasts using a chart which relates rainfall and runoff (Figure 9). The "Final Index" shown in the chart is a value supplied each week by the National Weather Service for each watershed. It incorporates numerous variables affecting the relationship between rainfall and runoff such as antecedent moisture, and humidity. The chart is not applicable to conditions of snowmelt or rainfall on frozen ground.

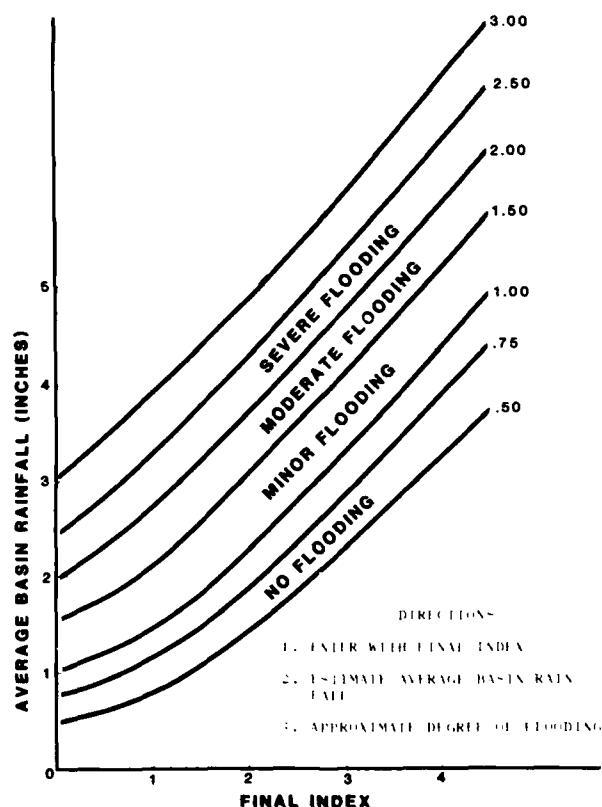


FIGURE 9. CHART USED FOR FLOOD PREDICTION IN LYCOMING COUNTY FLOOD WARNING SYSTEM.

Telephone is the primary means of communication between observers, stream coordinators, and the warning system coordinator. However, because of the vulnerability of telephone service to disruption in remote rural areas where





*Amateur radio operators provide communications for the flood warning system if telephone service is disrupted.*

observers are located, backup communications are provided by amateur radio operators. The system coordinator uses a mobile radio provided by the NWS.

Forecasts developed by the NWS are coordinated with the County and a Sprout-Waldron representative. Dissemination of information to the public begins when all parties agree that a flood warning is required. The Director of Emergency Services is then requested to issue an appropriate statement. Warnings are initially issued to the Red Cross, Pennsylvania Department of Transportation, Pennsylvania Power and Light Company, CONRAIL, several industries, and radio station WRAK which is the local Emergency Broadcast System station. Other radio stations serving the County obtain the warning message from station WRAK and repeat it. Two of the stations boost power to assure that messages are transmitted to remote areas of the County. Equipment is being installed to enable simultaneous broadcasting over all area radio stations from the warning system headquarters. Warnings are also issued over various NOAA channels, including NOAA Weather Radio. Stream coordinators are given hourly updates on flood forecasts for their watershed. These forecasts are passed along to observers for their use in advising residents in their respective areas.

County civil defense agencies and fire companies use fixed siren systems to alert populated areas to flood emergencies. Both police and fire forces use mobile public address systems to disseminate warning.

Numerous uses are made of flood warnings by public officials, business operators and the general public. These uses include:

- Scheduling closing of roads expected to be inundated.
- Checking readiness of pumping stations inside areas protected by levees and floodwalls.



*The County's warning system is used to ensure that workers and supplies are ready for emergency action when a flood strikes. These workers are at South Williamsport, Pennsylvania.*

- Parking of loaded trains on bridges to increase bridge stability.
- Preparation for flood fighting.
- Actions to reduce damages and danger by evacuation, temporary relocation of contents, and contingency flood-proofing.

The Lycoming County flood warning system is also coordinated closely with similar systems in adjacent counties. Thus, early information on rains and high flows are obtained before flooding reaches the County. Conversely, flood predictions made through the Lycoming County system are used by downstream counties to anticipate the need for emergency action. A flood information communication protocol has been established between counties in the SEDA-COG region.

Formal flood preparedness arrangements in the County include standing contracts with schools and the Red Cross to provide shelter and food for evacuees. All local police organizations have mutual aid pacts with nearby jurisdictions for emergency assistance.

### **Planned Improvements**

Further improvements to the Lycoming County flood warning system are underway including:

- The Flood Plain Management Services Branch of the Baltimore District, Corps of Engineers, is collecting the information necessary to relate downstream water levels to those measured upstream. This will enable a quick analysis of conditions to confirm predictions made on the basis of rainfall.
- The Corps of Engineers is also preparing river stage forecast maps that identify the area inundated at various river stages. Data generated in preparing Flood Insurance Rate Maps for the National Flood Insurance Program are being used as the basis for the effort. The completed maps enable a property owner or operator to interpret NWS flood forecasts in terms of its meaning for a specific location. A series of maps have been prepared for Lycoming Creek.
- Lycoming County has been selected by the Pennsylvania Emergency Management Agency as one of the initial two counties in Pennsylvania to participate in the Integrated Flood

Observing and Warning System (IFLOWS), funded jointly by the NWS and the Appalachian Regional Commission. IFLOWS proposes to combine existing sensor, communication and computer technology with advanced forecasting and software techniques to provide timely guidance and advice to both state and local authorities responsible for the provision of emergency service to their citizens.



*A mini-computer at Lycoming County's Emergency Operating Center will enable rapid and accurate forecasting of floods based on rainfall reports automatically sent by radio from gages throughout the County.*

Equipment installed includes automatic radio reporting rain gages, a microprocessor to analyze data, and a computer terminal. The automatic equipment enables around-the-clock monitoring of rainfall. Gages have been sited in remote areas to supplement/complement the system of volunteer observers. The NWS is also preparing software for the computerized forecasting procedure which will provide faster and more detailed flood predictions.

- Arrangements for communications between stream coordinators and the system coordinator, presently by telephone, are also planned for upgrading. NWS anticipates funding to provide sufficient radios to link

these key parties and assure telephone system disruptions will not interrupt the flow of all data from observers.

- The Pennsylvania General Assembly has passed legislation authorizing the state to cost-share operation and maintenance costs of IFLOWS with the county based upon the proven success of the flood warning system.

## **Effectiveness**

The effectiveness of the Lycoming County flood warning system was evidenced in flooding which occurred March 5-6 in 1979. At that time, a slowly moving early spring storm caused flooding along Muncy, Lycoming, Little Pine, and Pine Creeks and the West Branch Susquehanna River. Three hundred twenty-four homes were damaged by the flood. Some structures received up to several feet of water above first floor levels and one structure was swept away. Warnings of the impending flooding were issued every 30 minutes, each predicting levels to be reached in the succeeding 4-6 hours. Predicted flood levels were within 1 foot of the approximately 13 foot level that actually occurred. Early warnings gave residents in affected areas enough time to move items from basements and first floors. As a result, damages were reduced by approximately \$700,000.

One of the most significant benefits of the flood warning system is its contribution to safety. Prior to establishment of the warning system, it was often necessary to use motorboats to rescue people who had become trapped by unexpected high water levels. That posed a tremendous hazard for both the rescuers and those being assisted. The early warning system makes it possible to avoid those kinds of dangers by evacuating areas before they're flooded. The advance warnings also eliminate a great deal of chaos because the emergency agencies have time to prepare for action.

The Lycoming County flood warning system has been acclaimed throughout

the state as a model for other counties. The Pennsylvania Emergency Management Agency, which has assumed responsibility for establishing a flood warning system in each county, has conducted regional training sessions using personnel from Lycoming County as instructors. In addition, the Pennsylvania Department of Community Affairs includes as one of its training programs for local government officials a class on flood warning systems taught by Lycoming County personnel.

## **Observations on the Case Study**

Several points in the case study warrant emphasis because they are relevant to the efforts of other communities and industries to reduce flood losses. The points are arranged into three groups: industrial flood preparedness, flood warning systems and cooperative efforts.

### **About Industrial Flood Preparedness**

- An effective program to reduce flood losses can be carried out unilaterally by owners of industrial property. Sprout-Waldron made adjustments made to their facilities and operations without any governmental aid and assistance. The technical capability to carry out many types of adjustments is likely to be available among the staff of most large industries.
- Support of management is critical to successful development and use of preparedness procedures. Adjustments such as those made by Sprout-Waldron have a significant aggregate cost. Original preparation and periodic updating and review of the preparedness plan also require significant amounts of staff time. In addition, management personnel must also devote their time to maintain familiarity with the plan and make decisions regarding its implementation. From a management standpoint, justification

for the cost of a flood preparedness program lies in potential savings--the differences in losses which would be experienced with and without the program. The example of Sprout-Waldron's savings due to flood preparedness provide convincing evidence that, in at least some cases, benefits can exceed costs by a very large margin.

- Adjustments which are each minor on an individual basis can have a significant cumulative effect. This is evidenced in the case of Sprout-Waldron's evacuation plan by the dramatic reduction of damages achieved through the combination of relatively minor actions such as elevating a few key pieces of equipment, installing quick disconnect electrical fittings and preparing a schedule for evacuation.
- An effective program will combine a variety of techniques suited to the problem at hand rather than being limited to one approach. Adjustments to flooding made by Sprout-Waldron include: flood warning, permanent floodproofing, contingency floodproofing, permanent relocation, emergency evacuation, and recovery. No single measure would have been as cost-effective in providing the breadth and degree of protection to structures and contents which was achieved by their joint use.
- Warning is an essential ingredient of programs which depend to any significant extent on contingency actions to reduce damages and hazard to life. Sprout-Waldron's flood emergency plan requires approximately twelve hours to completely implement. Advance knowledge of impending floods is critical to allow time for assembling workers, scheduling trucks, and taking other steps to implement the firm's emergency plan.
- Post-flood clean up and restoration of productivity can be speeded dramatically by advance preparations, resulting in sizable reduction of business interruption costs. The time for Sprout-Waldron to resume produc-

tion at near capacity after a severe flood was reduced by approximately 93 percent. Losses due to interruption of business were consequently lowered by about 94 percent.

- Attention must be given to details as well as to the more major and expensive adjustments to flooding. Examples in the case of Sprout-Waldron's adjustments include stockpiling of equipment and material required for clean up which might be in short supply after a flood, provision of emergency lighting, and arrangement of equipment for easy access during an evacuation.
- Adjustments undertaken for flood-related purposes can also serve to make normal operations more efficient. Modifications made to equipment by Sprout-Waldron to facilitate rapid evacuation eases routine maintenance and repair tasks and reduces the need for electricians, plumbers and other skilled labor.
- Industrial preparations for floods should include specific written plans for emergency action. These plans should detail resources needed to carry out the preparations and specific assignments of responsibility for their accomplishment. Such plans enable undertaking emergency actions in an orderly fashion and ensure no critical steps will be overlooked. Written plans provide the means of carrying over experience and improving performance from one flood to another. They provide a tool for keeping management and staff aware of the flood hazard and appropriate flood response. They also help managers in making decisions to ensure building modifications and other routine actions do not compromise the plant's preparedness for floods.
- Costs of post-flood cleanup are minimized if work begins just as soon as flood levels have receded. Residue left by flood waters can be hosed away if removed before drying. Other types of damage, such as rusting of

equipment, may become progressively greater until cleanup is begun.

## About Flood Warning Systems

- Flood warning systems need not be expensive or technically complex in order to be successful. The Lycoming County flood warning system required an out of pocket cost of only \$500 for its establishment. It is also straightforward in operation, involving no complex operational procedures. Despite its simplicity and low cost, the system has functioned effectively.
- Flood warning systems can be implemented quickly with little or no assistance from the federal and state government. The Lycoming flood warning system was established and operational within three months of the initial organizational meeting. Assistance from the federal and state governments was limited to general guidance on how to proceed, contribution of rain gages and metal tapes for staff gages and provision of the forecasting charts.
- Flood warning systems produce a wide range of benefits for local governments, industry, and the general public. Early warnings help protect public safety and enable timely initiation of emergency actions to reduce damages. A \$700,000 reduction in damages during a single 1979 flood was attributed to the Lycoming County flood warning system.
- Flood warning systems are useful in conjunction with levees and other protective measures. At Williamsport, for example, early identification of the severity of floods helps to determine whether flood levels will exceed the design capability of the levee and floodwall. Early warning also enables pre-flood checks to assure pumping stations, closures and other project components are fully operational.

## Cooperative Efforts

- Cooperative efforts between government and industry can have a synergistic effect with significant mutual benefits. Operation of the Lycoming County flood warning system is a cooperative effort involving County government, Sprout-Waldron and the National Weather Service. The County's participation provides a basis for organization and wider range of geographic coverage for rain and stream reports and for issuing warnings in specific hazard areas in small watersheds. Industry would not accept the public warning responsibility and the NWS could not provide specific information on county streams. Contributions of labor and materials by Sprout-Waldron and other business firms enabled a better equipped system than would have been resulted from the investment of only County funds and labor. All parties served by the system are benefitted by the more comprehensive warning program made available through these joint efforts.
- The information and assistance needed to initiate a cooperative flood loss reduction program is readily available. Establishment of the Lycoming County Flood Warning System and improvements in preparedness arrangements were and are being assisted by the National Weather Service, Army Corps of Engineers, State of Pennsylvania and the Susquehanna River Basin Commission. The National Weather Service and Army Corps of Engineers offer such assistance throughout the Nation. Staff in their offices can usually also suggest potential local sources of assistance.
- A latent receptivity to cooperative flood loss reduction efforts exists in areas which have been flooded. In the case of Lycoming County, watershed associations, industries and businesses, churches, other organizations and the general public were all familiar with the flood problem and had experienced the effect of serious floods. The need for action was appre-

ciated and their assistance was forthcoming as soon as leadership was provided.

- Efforts to initiate a cooperative flood loss reduction program should include clear assignments of responsibility for leadership. Lycoming County's Board of Commissioners made the County's Planning Commission accountable for establishment of the flood warning system and gave a strong mandate for its development. This provided the emphasis needed for the agency to give priority to the effort and led to early implementation of the system. At Sprout-Waldron, the assignment to develop a flood preparedness program was given to the

plant engineering department. These clear assignments of responsibility provided a firm basis for each party to proceed; cooperation served their mutual self interests.

- Cooperative efforts between government and industry on a flood loss reduction program can set the stage for cooperative efforts of other types. The joint operation of the Lycoming County flood warning system by government and industry provides an opportunity for development of the personal acquaintances and understanding of each party's procedures and problems which facilitates better cooperation in the future. It also demonstrates to each party the mutual benefits of such cooperative effort.

## APPENDIX A REFERENCES

The following publications provide additional information concerning measures for flood loss reduction.

Available from the Federal Emergency Management Agency, 500 C Street Southwest, Washington, DC 20472.

Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas.

Economic Feasibility of Floodproofing: Analysis of a Small Commercial Building.

Elevating to the Wave Crest Level; A Benefit Cost Analysis.

Flood Emergency and Residential Repair Handbook.

The National Flood Insurance Program: Questions and Answers.

Reducing Flood Damage Through Building Design: A Guide Manual.

Elevated Residential Structures.

A Guide for Community Permit Officials.

Available from the National Weather Service, National Oceanic and Atmospheric Administration, Silver Spring, MD 20910

Guide for Flood and Flash Flood Preparedness Planning.

Flood Warning Systems: Does Your Community Need One?

Available from the Office of the Chief of Engineers, HQDA (DAEN-CWP-F), 20 Massachusetts Ave., N.W. Washington, DC 20314

Flood-Proofing Regulations.

Flood Plain Regulations for Flood Plain Management.

Introduction to Flood Proofing.

Available from the U.S. Water Resources Council, 2120 L Street N.W., Washington, DC 20037

Acquisition of High Hazard and Other Critical Areas by State and Local Governments

Floodplain Management Handbook.

Regulation of Flood Hazard Areas to Reduce Flood Losses (Vols. 1, 2 and 3).

Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151.

A Process for Community Flood Plain Management. (PB80-135296).

Available from the Susquehanna River Basin Commission, 1721 N. Front Street, Harrisburg, PA 17102.

Planning Guide: Self-Help Flood Forecast and Warning System, Swatara Creek, Pennsylvania. (Revised Edition 1978) Publication No. 42.

Available from Pennsylvania Department of Community Affairs, Bureau of Community Planning, P.O. Box 155, Harrisburg, Pennsylvania 17120.

Reducing Flood Vulnerability: Planning for the Evacuation and Protection of Flood-Prone Businesses.

Industrial Flood Preparedness: Proceedings of the Flood Warning and Flood Proofing Seminar for Industry. April, 1979.



## **APPENDIX B**

### **SOURCES OF ASSISTANCE**

Various types of assistance in reducing flood losses are available from federal agencies, regional organizations, states, and substate organizations. This appendix lists addresses and telephone numbers of the most prominent sources of assistance as of June 1981.

Each agency or organization covers a different facet of floodplain management and varies in the assistance it can provide. Those seeking assistance should therefore contact all of the relevant agencies to determine which offer the help most pertinent to local needs.

#### **Federal**

Table B-1 summarizes the principal types of information and assistance available from federal agencies. The following sections briefly describe pertinent activities of each agency and list points of contact.

#### **Army Corps of Engineers**

The Corps district and division offices provide information and assistance in flood-related matters. They maintain a file of floodplain information, survey and other reports containing floodplain delineations, flood profiles, data on discharges and hydrographs, and pertinent data on operational and planned flood control projects. Each office: a) provides interpretations as to flood depths, velocities, extent of flooding, flood frequency, flood formation, timing, and durations from existing data; b) develops new data through field and hydrologic studies for interpretation; and c) provides guidance on adjustments to minimize the adverse effects of floods and floodplain development.

The Corps also constructs flood control projects pursuant to congressional authorization. Major projects such as large dams and reservoirs are usually operated by the agency.

During flood emergencies, the Corps can assist states and communities by providing materials, equipment, and personnel for flood fighting and construction of temporary levees or other protective structures. Assistance is also available for rehabilitation of damaged public facilities and protective works.

Further information on available assistance and the location of Corps district offices can be obtained from the following field offices of the agency:

North Atlantic Division  
90 Church St.  
New York, NY 10007  
212/264-7483

South Atlantic Division  
510 Title Bldg.  
30 Pryor St. SW  
Atlanta, GA 30303  
404/221-6702

Southwestern Division  
Main Tower Bldg.  
1114 Commerce St.  
Dallas, TX 75242  
214/767-2310

South Pacific Division  
630 Sansom St.  
Rm. 1216  
San Francisco, CA 94111  
415/556-5660

Lower Mississippi Valley Division  
1400 Walnut St.  
Vicksburg, MS 39180  
601/634-5843, Ext. 385

TABLE B-1  
INFORMATION AND ASSISTANCE FROM FEDERAL AGENCIES

Types of Information and Assistance	Army Corps of Engineers	Bureau of Land Management <sup>1</sup>	Federal Emergency Management Agency	National Weather Service	Soil Conservation Service	Tennessee Valley Authority <sup>2</sup>	U.S. Geological Survey	Bureau of Reclamation <sup>3</sup>
<u>Information on the Flood Hazard<sup>4</sup></u>								
Hydrologic Data	X		X	X	X	X	X	X
Meteorological Data				X		X		
Streamflow Data	X		X	X	X	X	X	X
Historic Floods	X		X	X	X	X	X	
Flood Characteristics	X		X	X	X	X	X	
Storm Surge Data	X		X	X				
Floodplain Delineation	5	X	X		5	5	5	
<u>Technical Assistance In Planning</u>								
Dams & Reservoirs	X				X			X
Levees & Walls	X				X			X
Channel Alterations	X				X			X
Diversions	X				X			X
Land Treatment		X			X			
Onsite Detention	X				X			
Floodplain Regulations	X		X		X	X		
Development & Redevelopment	X		X		X	X		
Warning and Preparedness	X		X		X	X		
Floodproofing	X		X		X	X		
Flood Insurance			X			X		
Relief & Recovery	X		X		X			
<u>Assistance in Implementation</u>								
Dams & Reservoirs	6				X			
Levees & Walls	6				X			
Channel Alterations	6				X			
Diversions	6				X			
Land Treatment					X			
Onsite Detention					X			
Floodplain Regulations	X		X			X		
Development & Redevelopment	6	6				7		
Warning & Preparedness	6			X	X	7		
Floodproofing	6				6	7		
Flood Insurance			X					
Relief & Recovery	X		X		X			

<sup>1</sup>Operates in states of AK,AZ,CA,CO,ID,MI,NV,NM,OR,VT, and WY.

<sup>2</sup>Operates in states of AL,GA,KY,MS,NC,TN and VA.

<sup>3</sup>Operates in states of AZ,CA,CO,ID,KS,MT,NE,ND,NM,NV,OK,OR,SD,TX,UT, WA, and WY.

<sup>4</sup>Only principal sources of information are shown. All agencies may have relevant data for selected areas.

<sup>5</sup>Will provide existing file data upon request; develops new data and sometimes undertakes investigations upon request if funds and manpower are available.

<sup>6</sup>Financial assistance available pursuant to congressional authorization of specific projects. Otherwise only technical assistance is available.

<sup>7</sup>Available funds are used to help communities finance local flood loss reduction measures as part of broader community development and redevelopment efforts.

Missouri River Division  
12565 W. Center Rd.  
Omaha, NE 68101  
402/221-7270

North Central Division  
536 S. Clark St.  
Chicago, IL 60605  
312/353-6531

Ohio River Division  
550 Main St.  
Cincinnati, OH 45201  
513/684-3012

North Pacific Division  
220 N.W. 8th Ave.  
Portland, OR 97208  
503/221-3823

New England Division  
424 Trapelo Rd.  
Waltham, MA 02154  
617/894-2400, Ext. 545

Pacific Ocean Division  
Bldg. 230  
Fort Shafter, HI 96858  
808/438-2883

## **Bureau of Land Management**

The Bureau of Land Management has district offices located in the 11 western states and Alaska which are involved in land use planning for public lands. Each district office maintains a file of existing floodplain maps which are available for public inspection. District offices of the Bureau of Land Management are located at:

555 Cordova St.  
Anchorage, AK 99501  
907/277-1561

Federal Bldg. Rm. 3022  
Phoenix, AZ 85025  
602/261-3873 for FTS

Federal Office Bldg.  
Rm. E-2841  
2800 Cottage Way  
Sacramento, CA 95825  
916/484-4676

Room 700  
Colorado State Bank Bldg.  
1600 Broadway  
Denver, CO 80202  
303/837-4325

Room 398, Federal Bldg.  
550 West Fort St.  
P.O. Box 042  
Boise, ID 83724  
208/342-2711

Federal Bldg. & U.S. Courthouse  
222 E. 32nd St.  
P.O. Box 30157  
Billings, MT 59107  
406/245-6711

Federal Bldg., Rm. 3008  
300 Booth St.  
Reno, NV 89509  
702/784-5451

U.S. Post Office & Federal Bldg.  
South Federal Place  
P.O. Box 1449  
Santa Fe, NM 87501  
505/988-6217

729 N.E. Oregon St.  
P.O. Box 2965  
Portland, OR 97208  
503/234-3361, Ext. 4001

University Club Bldg.  
136 East South Temple  
Salt Lake City, UT 84111  
801/524-5311

Joseph C. O'Mahoney Federal Ctr.  
2120 Capitol Ave.  
P.O. Box 1828  
Cheyenne, WY 82001  
307/778-2326

## **Federal Emergency Management Agency**

The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program (NFIP) as well as programs for disaster planning and recovery. Specifically, the NFIP is administered by the Federal Insurance Administration (FIA). FIA's prime objective is to support state and local efforts to make the NFIP work in com-

munities. To accomplish this objective, FIA provides communities with up-to-date mapping and helps in using this information as a tool for administering the NFIP floodplain management rules and regulations.

Some of FEMA's Services are:

- County level seminars for building inspectors and other municipal officials.
- Planning assistance for developing local regulations to meet the program's floodplain management requirements.
- Engineering assistance on questions about the siting of structures in flood hazard areas.
- Assistance in evaluating possible flood hazard mapping errors and in initiating the required changes.

Another FEMA responsibility is to see that the NFIP's Standard Flood Insurance Policy is properly promoted and written. The EDS Federal Corporation is under contract with the NFIP to assist with these marketing-related responsibilities.

Regional offices of FEMA are located at:

Room 405A  
John F. Kennedy Federal Bldg.  
Boston, MA 02203  
616/223-2616

26 Federal Plaza  
New York, NY 10007  
212/264-4756

Curtis Bldg.  
Sixth and Walnut Streets  
Philadelphia, PA 19106  
215/597-9581

1371 Peachtree St. N.E.  
Atlanta, GA 30309  
404/526-2391

300 South Wacker Drive  
Chicago, IL 60606  
312/353-0757

New Federal Bldg.  
1100 Commerce St.  
Dallas, TX 75202  
214/749-7412

Federal Office Bldg.  
911 Walnut Street  
Kansas City, MO 64106  
816/374-2161

Federal Bldg.  
1961 Stout St.  
Denver, CO 80202  
303/837-2347

450 Golden Gate Ave.  
P.O. Box 36003  
San Francisco, CA 94102  
415/557-3543

Bothell, WA 98111  
206/481-8800

## National Weather Service

The National Weather Service issues weather forecasts and flood warnings. It also provides assistance to communities in establishing flood warning systems and conducting flood hazard analyses. The agency utilizes a network of about 7,900 precipitation and stream flow stations to support its flood forecast and warning services for about 2,500 communities. Types of information and assistance available include precipitation records and other climatological data; preparation of forecasting materials; assistance in organization and training of observers and those responsible for applying self-help warning systems; equipment installation and calibration; and stream data such as depth.

An annual publication entitled River Forecasts Provided by the National Weather Service, lists the locations at which data are compiled and includes the flood stage as well as the maximum stage of record at each location.

For further information on available data and assistance, contact the closest of the following National Weather Service regional offices:

Eastern Region  
585 Stewart Ave.  
Garden City, NY 11530  
212/905-8039

Southern Region  
819 Taylor St.  
Rm. 10E09  
Fort Worth, TX 76102  
817/334-2674

Central Region  
601 E. 12th St.  
Rm. 1736  
Kansas City, MO 64106  
816/374-3229

Western Region  
Box 11188 Fed. Bldg.  
125 S. State St.  
Salt Lake City, UT 84147  
801/524-5137

Alaskan Region  
Box 23  
701 C. St.  
Anchorage, AK 99513  
907/265-4716

Pacific Region  
Fed. Bldg. Rm. 4110  
Box 50027  
300 Ala Moana Blvd.  
Honolulu, HI 96850  
808/546-5680

Storm surge frequency information is also available. Studies have been completed for the Gulf of Mexico coast from the Alabama-Florida border to southern Florida; and along the Atlantic coast from southern Florida to Cape Henlopen, DE. The National Weather Service also provides warnings of storm surges associated with tropical and extratropical storms. For storm surge frequency information and interpretative assistance contact:

Chief, Water Management  
Information  
NWS Office of Hydrology (W21)  
8060 13th Street  
Silver Spring, MD 20910  
301/427-7543.

## Soil Conservation Service

The Soil Conservation Service carries out cooperative floodplain management studies, at the request of local governments, which include flood hazard photomaps, flood profiles, and floodplain management recommendations. The agency also provides technical and financial assistance to:

- Plan, design and install watershed projects of less than 250,000 acres.
- Install emergency work such as stream-bank stabilization, debris removal from channels and bridges, and re-vegetation of denuded and eroded areas to protect life and property after storms and floods.

Types of information available from the Soil Conservation Service include: land treatment needs; project planning data; photomosaic maps delineating areas subject to inundation by floods of selected frequency and associated flood profiles; location, floodplain management options (structural and nonstructural), design and construction information on flood prevention works; detailed soil survey data and maps; and snow survey data. In addition, the Soil Conservation Service provides continuing technical assistance to local governments after completion of a study to assist in implementation of local floodplain management programs.

Information can be obtained from the state office or county office of the Soil Conservation Service. Its location can be obtained by consulting your local telephone directory under U.S. Government, Department of Agriculture.

## Tennessee Valley Authority

The Tennessee Valley Authority's (TVA) activities in water resources are confined to portions of the states in the Tennessee Valley Watershed (AL, GA, KY, MS, NC, TN, VA).

The Floodplain Management Branch provides information, technical data, and other assistance in an effort to promote wise floodplain management practices. TVA maintains a file of floodplain information along with local flood study reports containing floodplain delineations, flood profiles, and other pertinent data. TVA further assists in the interpretation and use of existing data and will, on occasion, undertake additional studies to provide a factual technical basis for making decisions on proper floodplain use. Assistance is provided to communities in development and administration of local floodplain regulations and other floodplain management measures, including several instances where comprehensive measures have been implemented. For information contact:

Tennessee Valley Authority  
Flood Plain Management Branch  
100 Liberty Building  
Knoxville, TN 37902  
615/632-4451.

## **U.S. Geological Survey**

The U.S. Geological Survey maintains a network of about 7,700 continuous record streamflow gaging stations throughout the United States and Puerto Rico. Several thousand additional high-flow stations supplement this network. Many gaging stations are serviced periodically by "observers" who generally reside near the gage site. Arrangements for direct telephone notification of flood conditions can usually be made with observers.

The U.S. Geological Survey publishes an annual report entitled Surface Water Records (often called Water Supply Papers) which includes records of gage height, discharge, runoff, time of travel, and sediment discharge from a network of gaging stations. The agency also has information available on historic flood peaks and inundated areas and the magnitude, frequency and duration of flood flows. Areas subject to inundation by floods

of selected frequencies, usually 100-year floods, have been delineated on topographic maps for:

- Urban areas where the upstream drainage basin exceeds 25 square miles and smaller drainage basins depending on topography and potential use of the flood plains.
- Rural areas in humid regions where the upstream drainage basin exceeds 100 square miles.
- Rural areas in semiarid regions where the upstream drainage basin exceeds 250 square miles.

Assistance is also available in interpreting flood-frequency relations and computed water surface profiles, and in identifying areas of potential flood hazard.

Information concerning the availability of information for a specific community can be obtained from the closest district office of the U.S. Geological Survey. Its location can be obtained from the State contact listed later in this appendix.

## **Bureau of Reclamation**

A flood hydrologist at each of the seven regional offices of the Bureau of Reclamation has knowledge of flooding and flood elevation for locations associated with projects and can provide interpretive assistance for existing data. The agencies activities are limited to the Nation's 17 western states.

For information contact the nearest of the following regional offices:

Federal Office Bldg.  
2800 Cottage Way  
Sacramento, CA 95825  
916/484-4571

Building 20  
Denver Federal Center  
Denver, CO 80225  
303/234-4441

P.O. Box 043  
550 West Fort St.  
Boise, ID 83724  
208/342-2101

P.O. Box 2553  
Billings, MT 59103  
406/585-6214

P.O. Box 427  
Boulder City, NV 89005  
702/293-8411

Herring Plaza  
Box H-4377  
Amarillo, TX 79101  
806/376-2401

P.O. Box 11568  
Salt Lake City, UT 84147  
801/524-5592

New England River Basins  
Commission  
53 State Street  
Boston, MA 02109  
617/223-6244

Ohio River Basin Commission  
36 East Fourth Street  
Cincinnati, OH 45202  
513/684-3831

Pacific Northwest River Basins  
Commission  
1 Columbia River  
Vancouver, WA 98660  
206/694-2581

Upper Mississippi River Basin  
Commission  
Federal Building, Rm. 510  
Fort Snelling  
Twin Cities, MN 55111  
612/725-4690

## River Basin Commissions

Federal-State River Basin Commissions and Interstate Compact Commissions have been organized for several major river basins. These organizations are generally responsible for coordination of water and related land resources development within their areas, including floodplain management activities.

Most if not all of the commissions have an extensive collection of information and data pertinent to flood hazards and floodplain management. They also can provide technical assistance in interpreting such data and suggest sources of further information and assistance. Headquarters of the several regional organizations are located as follows:

### River Basin Commissions

Great Lakes Basin Commission  
3475 Plymouth Road  
P.O. Box 999  
Ann Arbor, MI 48106  
313/668-2300

Missouri River Basin Commission  
Suite 403  
10050 Regency Circle  
Omaha, NE 68114

### Interstate Compact Commissions

Delaware River Basin Commission  
P.O. Box 7630  
West Trenton, NJ 08628  
609/883-9500

Susquehanna River Basin  
Commission  
1721 North Front Street  
Harrisburg, PA 17102  
717/238-0425

## State Contacts

Many States have active floodplain management programs. They have access to most floodplain information generated by federal and state agencies, regional organizations, special districts and private consultants. State agencies are usually staffed and funded to: a) coordinate floodplain management activities; b) develop minimum standards for floodplain regulations; c) assist local units of government (counties, cities, etc.) in developing floodplain management programs; and d) interpret available floodplain information.

The following agencies are responsible for coordination of the National Flood Insurance Program in their respective states. They generally can either provide assistance directly or refer inquiries to other appropriate agencies.

Alabama Development Office  
State Planning Division  
State Capitol Building  
Montgomery, AL 36130

Alaska Department of Community  
and Regional Affairs  
Division of Community and  
Regional Planning  
225 Cordova, Bldg. B  
Anchorage, AK 99501

Arizona Water Commission  
Flood Control Division  
222 North Central  
Phoenix, AZ 85004

Division of Soil and Water  
Resources  
State Department of Commerce  
1818 W. Capitol Bldg.  
Little Rock, AR 72202

Department of Water Resources  
P.O. Box 388  
Sacramento, CA 95802

Colorado Water Conservation Board  
Room 823, State Centennial Bldg.  
1313 Sherman St.  
Denver, CO 80203

Department of Environmental  
Protection  
Division of Water and Related  
Resources  
Rm. 215, State Office Bldg.  
Hartford, CT 06115

Office of Management, Budget  
and Planning  
Townsend Bldg., 3rd Floor  
Dover, DE 19001

Office of Environmental Planning  
& Mgmt.  
415 12th Street N.W.  
Washington, DC 20040

Department of Community Affairs  
2571 Executive Center Circle East  
Howard Bldg.  
Tallahassee, FL 32301

Department of Natural Resources  
Environmental Protection Division  
270 Washington Street, S.W.  
Atlanta, GA 30334

Board of Land and Natural Resources  
Department of Land and  
Natural Resources  
P.O. Box 621  
Honolulu, HI 96809

Department of Water Resources  
State House  
Boise, ID 83720

Illinois Department of Transpor-  
tation  
Division of Water Resources  
300 North State Street  
Room 1010  
Chicago, IL 60610

Department of Natural Resources  
Division of Water  
605 State Office Bldg.  
Indianapolis, IN 46204

Iowa Natural Resources Council  
James W. Grimes Bldg.  
Des Moines, IA 50319

Division of Water Resources  
State Board of Agriculture  
901 Kansas Ave. Second Floor  
Topeka, KS 66612

Kentucky Department of Natural  
Resources  
Division of Water Resources  
Old Wilkinson Street  
School Bldg.  
Frankfort, KY 40601

Department of Urban & Community  
Affairs  
5790 Florida Blvd.  
Baton Rouge, LA 70806

Bureau of Civil Emergency  
Preparedness  
State House  
Augusta, ME 04330



Water Resources Administration  
Flood Control Section  
Tawes Office Bldg.  
Department of Natural Resources  
Annapolis, MD 21401

Division of Water Resources  
Water Resources Commission  
State Office Bldg.  
100 Cambridge Street  
Boston, MA 02202

Michigan Department of Natural  
Resources  
Water Management Division  
Steven T. Masons Bldg.  
P.O. Box 30028  
Lansing, MI 48909

Department of Natural Resources  
Division of Waters  
Space Ctr. Bldg. Third Floor  
444 Lafayette Road  
St. Paul, MN 55101

Mississippi Research & Develop-  
ment Ctr.  
P.O. Drawer 2470  
Jackson, MS 39205

Disaster Planning & Operations  
Office  
P.O. Box 116  
Jefferson City, MO 65102

Montana Department of Natural  
Resources and Conservation  
Water Resources Division  
32 South Ewing Street  
Helena, Mt 59601

Nebraska Natural Resources  
Commission  
301 Centennial Mall  
P.O. Box 94876  
Lincoln, NE 68509

Department of Conservation  
and Natural Resources  
Division of Water Resources  
201 S. Fall Street  
Carson City, NV 89710

Office of State Planning  
Division of Community Planning  
State of New Hampshire  
2½ Beacon Street  
Concord, NH 03301

Department of Environmental  
Protection  
Bureau of Flood Plain Management  
Division of Water Resources  
P.O. Box 2800  
Trenton, NJ 08625

State Engineer's Office  
Bataan Memorial Building  
Santa Fe, NM 87501

New York State Department of  
Environmental Conservation  
Water Management  
50 Wolf Road, Rm. 618  
Albany, NY 12233

Division of Community  
Assistance  
Department of Natural and  
Economic Resources  
P.O. Box 27687  
Raleigh, NC 27611

State Water Commission  
State Office Bldg.  
900 East Boulevard  
Bismark, ND 58505

Ohio Department of Natural  
Resources  
Flood Plain Planning  
Fountain Square - Bldg. E  
Columbus, OH 43224

Oklahoma Water Resources Board  
Jim Thorpe Bldg., Rm. 500  
Oklahoma City, OK 73105

Water Resources Department  
555 13th Street, N.E.  
Salem, OR 97310

Department of Community Affairs  
P.O. Box 155  
Harrisburg, PA 17120

Puerto Rico Planning Board  
P.O. Box 41119, Minillas Sta.  
Santurce, Puerto Rico 00940

R.I. Statewide Planning Program  
265 Melrose Street  
Providence, RI 02907

South Carolina Water  
Resources Commission  
P.O. Box 4515  
3830 Forest Drive  
Columbia, SC 29240

State Planning Bureau  
State Capitol  
Pierre, SD 57501

Tennessee State Planning  
Office  
600 Capitol Hill Bldg.  
Nashville, TN 37219

Texas Department of Water  
Resources  
Flood Protection & Disaster  
Assistance  
1700 N. Congress Ave.  
Austin, TX 78701

Department of Natural Resources  
Division of Water Resources  
Suite 300 Empire Building  
321 E. 400 South  
Salt Lake City, UT 84114

Management and Engineering  
Division  
Water Resources Department  
State Office Building  
Montpelier, VT 05602

State Water Control Board  
P.O. Box 11143  
Richmond, VA 23220

Department of Ecology  
Olympia, WA 98504

Governor's Disaster Recovery  
Office  
State Capitol Complex  
Charleston, WV 25305

Department of Natural Resources  
Flood Plain-Shoreline Management  
Section  
P.O. Box 7921  
Madison, WI 53707

Wyoming Disaster & Civil Defense  
Agency  
P.O. Box 1709  
Cheyenne, WY 82001

## Substate

At the substate level, in addition to city, town and county offices, regional agencies such as conservancy districts and multi-county planning agencies may be a source of floodplain data and assistance in its interpretation. Information on the existence and location of such groups can be obtained from county or municipal planning departments.

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